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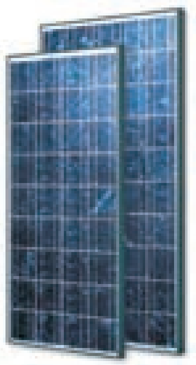

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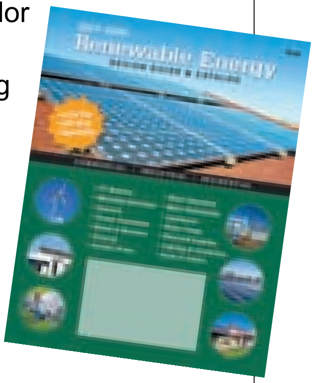

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contents

December 2007 & January 2008

Clockwise from lower left: redmal/iStockPhoto; courtesy Randy Richmond; courtesy Scott Franklin; courtesy Jeffe Aronson; courtesy Kevin Moore; courtesy Fronius; courtesy Sean Easly

On the Cover

Home Power wind energy expert Ian Woofenden atop a 165-foot tower on Washington's San Juan Islands. Visit www.homepower.com/covershoot to see how this photo was taken.

Photo by Shawn Schreiner

Regulars

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from us to you

Center photo: Shawn Schreiner

Boots in the Air

"It must be great to work in the renewable energy industry!" is one of the most common comments I hear from *Home Power* readers. My response is often something like, "Working in the RE field, you'll have a bad day every now and then, but you'll sleep well at night because the work you're doing is both positive and important." What I usually fail to mention is that there are also days that leave you thinking, "I can't believe I make a living doing this!"

Recently, I had two full "I can't believe it" days during the photo shoot for this issue's cover. The stage was atop Frank and Deb Dehns' wind generator tower, 160 feet off the ground on Guemes Island, Washington. My first trip up the tower was a few weeks earlier, when I was in the area with *Home Power's* advertising director Kim Bowker and art director Ben Root to install a PV system at Ben's mom's place in Anacortes. Kim and I decided to head over to the island so senior editor Ian Woofenden could take us up a few different towers to check out possible camera angles for the upcoming cover shoot.

I headed north to Washington again, this time with photographer and RE enthusiast Shawn Schreiner. The day before we arrived for the cover photo session, Ian, his son Zander, and their friend Doug Moser had been hard at work rigging a platform to get Shawn and his camera far enough away from the tower to get the shot. The staging they built was somewhere between ingenious and insane. We spent the better part of the next two days up in the air, on what we jokingly referred to as the "plank of death," as Shawn worked his Nikon.

If you look into the backstage workings of *Home Power*, you won't find us stagnating in cubicles in Anywhere, USA. We've got our boots on the ground—and in the air—to keep you informed about the practical uses of real-world RE technologies. And we're having a great time doing it.

—Joe Schwartz for the *Home Power* crew

Think About It...

"...a full-blown push for clean energy could unleash a jobs bonanza that would make what happened in Silicon Valley in the 1990s look like a bake sale."

—Jeff Goodell (see "Big Problems with Big Coal," page 60)

home power

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THE POWER OF MIDNITE SOLAR E-PANELS

OutBack shown mounted on a **MidNite Solar E-Panel**
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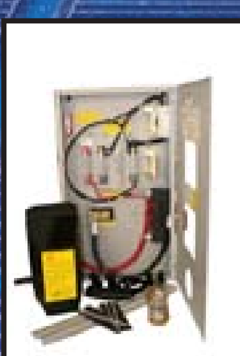
Which would you rather have, a nice new shiny box that takes up your entire wall or an even shinier, more compact system, and a $855 solar panel?



Check out the "E-Panels Explained" on our website for help in selecting the best E-Panel for your application

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Ask the EXPERTS!

Resource- & Energy-Efficient Building

My husband and I are planning to build a house. We'd like to do something sustainable, but it all seems so complicated. How can I be more earth friendly without breaking the bank, scaring off the lenders, or making my life crazy?

Jean McGuire • Palmyra, New York

It's great that you're considering sustainable design for your new home. First, assemble a qualified design and building team that is familiar with green building. By using a team with experience, you will save money and time compared to working with contractors without experience in energy- and resource-efficient building. Second, reduce costs and environmental impact up front by opting for a small home. Sarah Susanka's series of *The Not So Big House* books offer many creative examples of building small but functional spaces.

Courtesy Laura Bartels

One of the most cost-effective ways to minimize your home's energy use is to make sure that your home is oriented to take advantage of the sun, if your site allows. Put windows on the south side, and design overhangs to shade those windows in the summer when the sun's path is high in the sky, but allow solar energy into your home during the winter months when the sun's path is lower. Determining the ideal amount of south-facing glazing (windows) and calculating overhang dimensions is something your architect can do with very little extra cost. (See the passive solar design primer in *HP90*.)

The next important thing is to insulate, insulate, insulate. High levels of insulation will keep your heating and cooling energy use and costs down. With proper design and adequate insulation, mechanical cooling systems can be eliminated in some climates, further reducing up-front construction costs. To be truly "green," pick insulation and building materials that have low embodied energy.

Other energy-efficient strategies may cost a little more up front but will save you money in the long run. Investing in high-efficiency windows, efficient and thoughtfully placed lighting, and Energy Star-rated appliances will save you energy and money, will not scare off lenders, and may even qualify for tax credits.

There are many other sustainable approaches you can take when building a home, but if you are trying to stay within a certain budget, you may need to prioritize. Is the use of greener materials, such as wood products certified by the Forest Stewardship Council, non-VOC paints, and recycled glass countertops, important to you? Or would you rather spend your money on energy efficiency and renewable energy technologies, such as a solar hot water or a solar-electric system? The bottom line is that incorporating any of these strategies will help make your home more sustainable, and healthier for you, your family, and the planet.

Rachel Connor & Laurie Stone • Solar Energy International

Cold EV Batteries

I've read that batteries, in general, lose about half of their stored energy at 32°F. If I drive a fully charged (and garaged) electric vehicle to my graveyard-shift job, where it overnights in a parking lot and is exposed to freezing temperatures, won't at least 50% of the stored battery energy be lost, and I'll have to hitchhike my way back home?

Jim Cain • Meridian, Idaho

Courtesy Shari Prange

You might lose that much capacity if your battery got that cold internally. This is more likely with a car-starting battery, which sits alone and pretty open to the air. In an electric vehicle, you have a pack of batteries, so only the outside edges are exposed. In cold climates, it is recommended to build them into fully enclosed boxes, possibly insulated. This will help retain heat. Once the battery pack gets warm, it would take a couple days for it to sink to ambient cold.

Both charging and discharging generate heat in the battery. So driving the car every day and charging it every night will help keep batteries warm. If you can plug it in while you're at work, that's even better. Many cold climate areas have outlets available in parking spaces for block heaters on cars. These same outlets can perform a similar function for your batteries.

Technically, the energy stored in the battery is not lost; it is merely temporarily unavailable due to the temperature. Warm the battery up and the lost capacity is regained. At 32°F, a lead-acid battery will have an apparent capacity of 70% when compared with its rated capacity at 78°F. At -10°F, the battery will have an apparent capacity of 35%.

Shari Prange • Electro Automotive
Richard Perez • *Home Power*

Affordable Renewable Energy

I would love it if someone could suggest an affordable home solar energy system. For years we have wanted to switch over to "green energy," but have found it very cost prohibitive. How can an average family afford to make the switch? In our area, most families have average annual incomes between $30,000 and $70,000. Can solar and wind energy be affordable for these families?

Ronda Hillis • Abilene, Texas

There are a number of ways you can start your transition to cleaner energy—and for a whole lot less than you might think:

Increase Efficiency. This is probably the best first step, since the cleanest electricity is that which you don't use in the first place. There are dozens of changes you can make to your house that would require little financial outlay and realize immediate savings. Here in Texas, we spend the lion's share of our energy—and money—on keeping cool. You'll spend a lot less of both if you make a few simple changes. Install solar screens, film, or awnings to reduce the heat gain through your windows, and make sure your home is well insulated. Install high-efficiency air-conditioning equipment, and insulate and seal ductwork. Plant trees in strategic places to shade your home.

Significant and further reductions can be obtained by upgrading to high-efficiency appliances as old ones wear out and replacing incandescent lamps with compact fluorescents. Then, there's the time-honored, low-tech solution of just turning things off when they are not in use.

Buy Green Power. Not all Texans can choose their electricity provider, but in Abilene, you have access to more than ten companies offering a variety of green power programs. Each allows you to purchase electricity from renewable energy generation facilities, some just down the road, such as the 150-megawatt wind farm at Trent Mesa. To find out more about these programs, go to www.powertochoose.org and enter your zip code.

Make Your Own Green Energy. While renewable energy systems can indeed cost $50,000 or more, you don't have to spend that much. With solar-electricity, you can start with a system that fits your budget now and meets a portion of your energy needs (the rest being met from the utility as usual), and add to that system as time and budget allow. If you approach your renewable energy contractor with this as an objective, he or she should be able to design a modular system that fits your budget and can be easily expanded as you can afford it.

Andrew H. McCalla • Meridian Energy Systems

Artesian Hydro

I'm in the process of designing a microhydro-electric system that runs off artesian well overflow. The well discharges 25 gpm of clean, clear 50°F water year-round, no matter the weather. The well is located on a rise about 135 feet above a future house site and about 1,500 feet away. As far as I can tell, the only difficulty will be installing the piping from the well to the house. Can you identify any potential challenges to this system setup?

Steve Bartlett • via e-mail

Unless there is significant artesian pressure where the water comes out of the ground, whether the source falls down a hill or bubbles out of the ground doesn't matter—it's all about head (vertical drop) and flow. Water in the pipe run between the well and your turbine will build up pressure (2.31 PSI for every foot of drop) as the pipe runs downhill.

A basic calculation of estimated output shows that 25 gpm times 135 feet of head, divided by a standard factor of 13 for small systems, yields about 260 watts continuous. This times 24 hours per day is 6.2 kilowatt-hours per day. That's one-fourth to one-fifth of the electrical usage of a typical (inefficient) American home. A super-efficient home might run most or all of its electrical loads on this much energy.

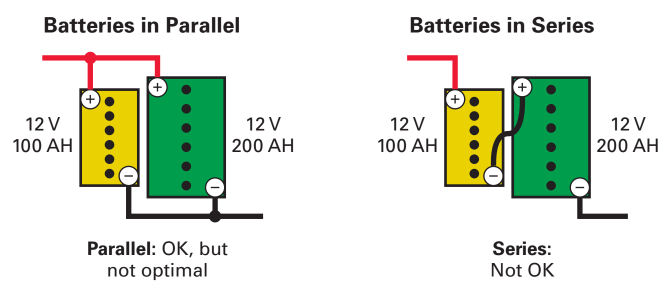
Your next step should be to check out the cost of an appropriately sized pipe and system components. With a 1,500-foot pipe run, it will probably be tough to make a solely economic case for this system unless it is expensive to hook up to utility electricity. But it could be fun and satisfying in other ways.

Ian Woofenden • *Home Power*

Batteries in Series & Parallel

What happens to the battery bank capacity, and the charging and discharging characteristics, when you connect a 12-volt (V), 100 amp-hour (AH) battery and a 12 V, 200 AH battery in series? Conversely, what happens when they are connected in parallel?

Sid Baxter • Pocatello, Idaho



Connecting two battery banks of different amp-hour capacity together in series is a bad idea. The problem is that the battery charging controls will operate based on the average battery voltage and the two batteries will have very different voltages because their capacities are different. The 100 AH battery will become fully charged long before the larger one. The combined voltage will rise, but by the time the controller turns off the charging sources, the 100 AH battery will be overcharged. Meanwhile, the 200 AH battery will not get fully charged. When the bank is being discharged, the 100 AH battery will go flat and its voltage will fall well before the 200 AH battery. The inverter will eventually cut out but not before the 100 AH battery is excessively drained.

Connecting two banks with different capacities in parallel is technically fine since the batteries will be operating at the same voltage. Charge and discharge current will be shared, based on capacity. It is best if the batteries are of the same type and age. For example, avoid combining a sealed (gel or absorbed glass mat) battery with a flooded (conventional) battery because they have different charging setpoints. Broadly speaking, you can parallel batteries without problems, and the charge controller will look after them. Just make sure you give them plenty of charge. If the system tends to operate at less than a full state of charge, adding new batteries to old will probably just result in the old ones pulling the new ones down and everything getting sulphated.

Hugh Piggott • Scoraig Wind Electric

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DIY Satisfies

I have always been intrigued by the idea of using water heated by the sun. For some strange reason—as it goes with many folks—I installed a solar-electric system on my home first, and solar hot water (SHW) came after. It makes much more sense to go with solar thermal first, with its relatively quick payback, better conversion efficiency, and much greater "bang for the buck." I guess solar thermal technology just isn't as sexy as solar electricity.

I chose a Thermomax 20-tube collector, mounted at a winter angle of about 60 degrees, since in the sunnier months the collector can easily produce more heat than I need. The storage tank is a 40-gallon Marathon water heater. I used a Quad Rod heat exchanger for heat transfer from the glycol loop to the domestic hot water.

Courtesy Jon Carroll (2)

Successfully installing a system myself and taking showers heated by the sun is quite satisfying!

A Tagaki instantaneous water heater backs up the system. The heater can modulate up and down to compensate for differing incoming water temperatures. I hooked up the Tagaki's electrical input to an AC switch on the wall. When I get up in the morning, I read the tank temperature before hopping into the shower. If the tank reads 45°C or higher, I leave the instantaneous water heater turned off. If the temperature is below 45°C, I switch on the heater to make up the difference. I could leave the heater on all the time, but it would initially fire up regardless of incoming water temperatures, wasting a bit of natural gas.

I have a small off-grid solar-electric system that I use for my computer, TV, stereo, light, and, occasionally, the SHW system's circulation pumps. I hooked up a transfer switch that, in the case of a utility outage, switches my SHW system over to the off-grid system so the circulation pumps can continue to run. Sometimes, during particularly sunny times, I just switch over to the off-grid system for a while to save a little grid electricity.

The performance of my SHW system has been impressive, to say the least. The system was commissioned on the winter solstice in 2006. Although it was the shortest day of the year, it was mostly sunny all day and the storage tank reached 123°F. The lowest tank temperature I have recorded, on the darkest, rainiest days of the winter, was about 77°F. For most of spring and all summer long, the backup heater was shut off completely.

I installed this entire system myself. The most helpful information came from none other than *Home Power* magazine. I downloaded several archived articles, which gave me the knowledge and confidence to do the installation myself. I had never sweated copper pipe before, but being a DIYer in most facets of my life, I was willing to give it a try. After fixing some initial minor leaks, it now all works like a charm. Successfully installing such a system myself and taking showers heated by the sun is quite satisfying!

Jon Carroll • Corvallis, Oregon

PV Pricing

Thanks for your PV Buyer's Guide in *HP121.* But it was disappointing not to be told the prices of PV modules.

William Savage • Seattle, Washington

We contemplated including module pricing in the PV guide spreadsheet but decided against it for a few reasons. First, PV module pricing changes frequently based on increases in PV manufacturing capacity, market demand, silicon supply constraints, and other factors.

In the end, specific module pricing is not usually the biggest decision-making factor…Size and electrical characteristics have a much greater bearing on module choice.

Any published pricing would have quickly become dated and not useful. Second, the cost of modules will vary depending on quantity purchased and who is installing the system. Some PV manufacturers do not even specify a MSRP for their product, depending on their distribution chain. Third, in general, there are not huge variations in cost per watt between different modules.

And in the end, specific module pricing is not usually the biggest decision-making factor, if it is even considered. Size and electrical characteristics have a much greater bearing on module choice. If you're having a system installed, your installer will only have a few different lines to work with, and he or she will be able to help you understand the choices. If you're a do-it-yourselfer, my suggestion is to determine which model or models will work best for your project, and then determine if current pricing is within your budget.

Joe Schwartz • *Home Power*

Pump Possibilities

In Chuck Marken's article "Pick the Right Pump" (*HP121*), he points out that "finding a reliable high-head DC pump for drainback systems is impossible at this

time." I have built several systems that have used high-head DC pumps—some with head as high as 30 feet. The last system I put together required 16 feet of lift. The system is described in detail in my article in *HP112.* The piston pump used is made by Thermo Dynamics Ltd. and can be powered by a 10- to 20-watt solar-electric module.

Initially, I had a differential controller controlling the pump, but after it failed, I connected the module directly to the pump. I like the simplicity and reliability of the system, although it can have a very small loss at the end of the day; when the water leaving the collector is several degrees cooler than the water at the top of the tank, the pump very slowly continues to circulate water through the collector. My article pointed out this problem, but I found this loss to be negligible because of the slow speed of the pump and the small amount the water temperature is decreased as it passes through the collector. On the other hand, the differential controller would shut the pump off early, slightly reducing the solar hot water collected. In a practical sense, both systems work well.

Larry Schlussler • Arcata, California

Questioning Subsidies

Given the space devoted to favoring solar subsidies in *Home Power* over the years, and doubtless the dependence on subsidies of most who advertise in your pages, Michael Welch is to be commended for even suggesting there could be something wrong with subsidies ("Show RE the Money," *Power Politics, HP121*).

Big money and big business determine big government. They regard clotheslines, daylighting, and passive solar design the way banks regard barter.

Courtesy Dottie Simmons

There is a lot wrong with subsidies, and particularly solar subsidies that leave fossil fuels solidly in place, because they distract the public from the best uses of the sun—daylighting, solar clothes drying, and passive heating—and have us concentrate on relatively uneconomic electricity generation.

Big money and big business determine big government. They regard clotheslines, daylighting, and passive solar design the way banks regard barter. If they can distract the solar crowd away from what might unravel their grip on us, and encourage us to continue to awkwardly and expensively make electricity when we don't need it, they've "got" us.

Steve Baer •
Albuquerque, New Mexico

RE After All These Years

First of all, we want to congratulate you on twenty years of ahead-of-the-curve articles and information. Second, we want to say how flattered we are to have a reprint of our old letter (*HP8* Dec. 1988/Jan. 1989) included in *HP120*! So here's an update: We are still on the same homestead making soap, and, I would say, it is all the same except it is always getting better. First, we added solar hot water panels, which are still working perfectly 25 years later. The addition of a Whisper H-80 wind generator a few years back makes it now the Simmons' Rain, *Wind*, or Sun System. This has really proved beneficial because 2007, especially, has been a particularly windy year. The gas water pump was replaced with two, 75-watt BP modules and a solar Slowpump to fill our holding tanks.

We also have made some progress on the endless upgrade to our PV system and are set up for twenty (but currently have fifteen) 85-watt mixed PV modules. Ultimately, we want to switch over to a 24-volt system and make the most of the house 120 volts AC, but since we started so long ago, it requires re-wiring

the house from 12 volts, which is at the bottom of the list right now. Our most exciting energy news is that we have gained access to an almost year-round water source 500 feet above our home. We hope to move our Harris hydro turbine up to that source instead of down by the river where it is working off an 80-foot drop from the pond overflow in winter only.

Meanwhile, the business keeps growing. We use more electricity on workdays but are keeping up, and there are very few times where any engine generator backup is needed. This is in spite of switching from a propane refrigerator to a Sun Frost, and my wholly decadent electric teakettle and bread machine. But that's offset by our addiction to solar cookers, which we have even used in the snow on sunny days!

Last but not least, one of those pillow-fighting kids grew up, married, and moved to a property nearby where she built an off-grid, straw-bale home—and on July 17, our new granddaughter was born. Our daughter works for us, and her husband installs RE systems for other folks, as well as helping with the soap production once a week. The best to all the *Home Power* crew. Keep up the good work.

Dennis & Dottie Simmons • Bridgeville, California

17 Years & Counting

You gave us the knowledge and resources to equip our first totally independent home seventeen years ago when folks had to find all their own pieces and put them together. We couldn't have done it without you. Today you are just as important in helping us weed through all the codes, regulations, prepackaged and engineered kits, and the new developments that are coming to the industry that you helped start. Thanks for twenty years of help, and please give us twenty more.

Steve & Lil Schroer • Egg Harbor, New Jersey

Where's Donald?

The e-mail address listed in the article for my solar scooter ("Sun-Charged Transportation," *HP120*) is no longer correct. Readers can now contact me at organicgrower@earthlink.net.

Donald Dunklee • Davidson, Michigan

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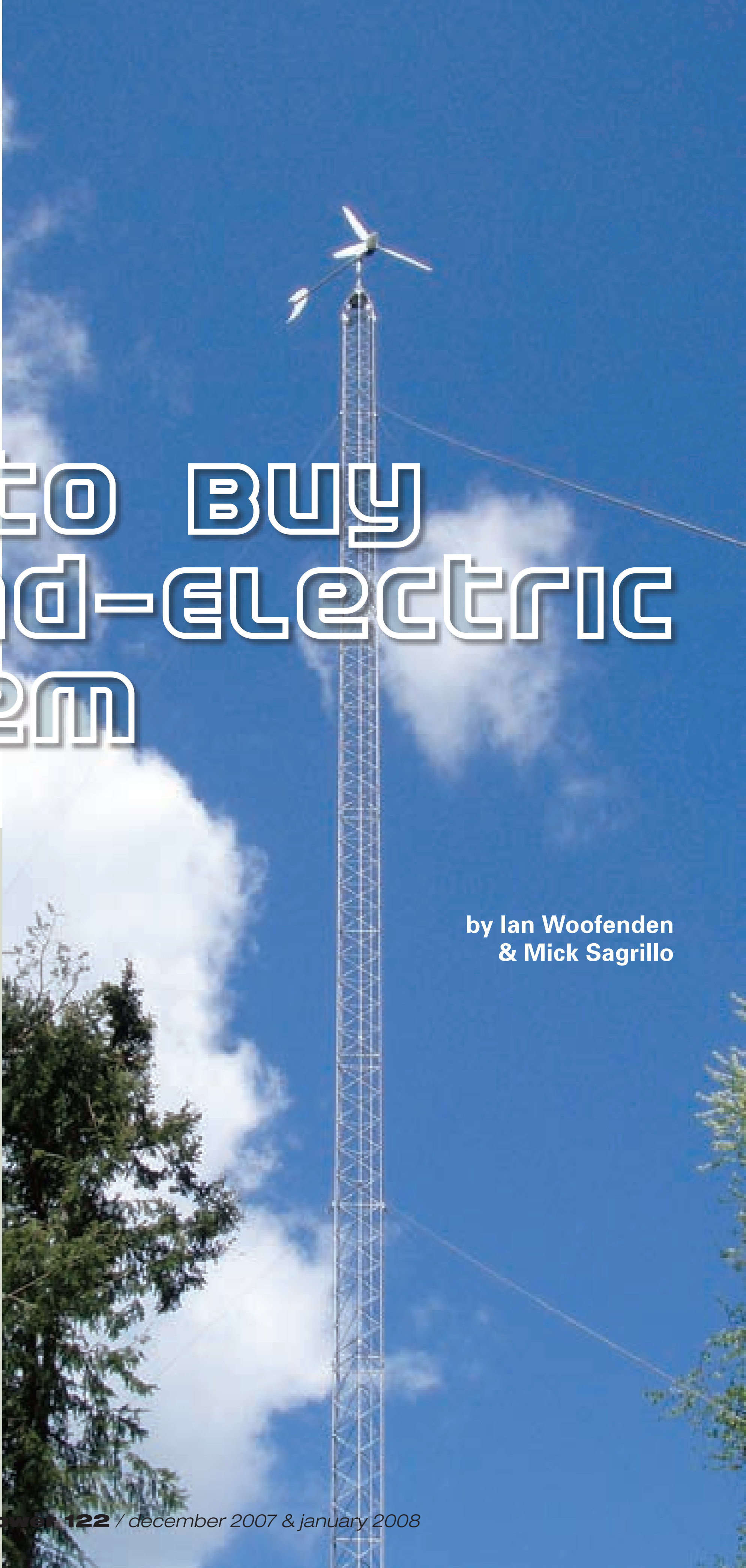
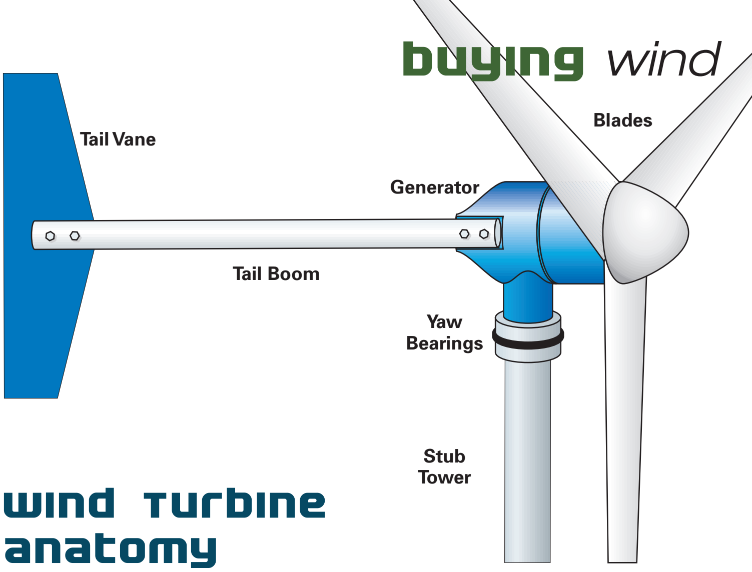
How to Buy a Wind-Electric System



by Ian Woofenden
& Mick Sagrillo

You've been dreaming about it for years, and now you're ready to plunk down the cash, put concrete in the ground, and put up a tower. You understand that you need to buy a *whole* system, not just a wind turbine. And you know that there must be an orderly set of steps to follow—a process. So how do you get from Point A (life before wind generator) to Point B (happy user of wind electricity)?

There's a lot of preparatory work to do before you get to see your wind turbine's blades spin. It includes understanding how much energy you need (or want), how to use energy efficiently, how much wind energy you have available at your site, and how to match your needs with your resource. After you've covered this ground, you can start to consider which wind turbine and what balance of system components to buy, and how to install them.



wind turbine anatomy

Energy Analysis First

If you want to install a wind-electric system, the first step is to determine how much electricity you use. Electrical energy is measured in kilowatt-hours (KWH), and one way or another, you need to discover how many of them you use per month. You could learn to read your utility meter and check it multiple times over the year. But it's easier to simply contact your utility, which will usually supply a summary of the past year's electrical usage.

If you're planning a new home, you'll need to estimate your electrical use. Reviewing utility bills from your current home may give you a good estimate if you're going to use a similar range of appliances. But in the end, this will only be a guess, since your actual usage may vary considerably.

The goal of the analysis is to come up with the number of KWH per year that you want your wind system to generate. Without this number, you're guessing, and may end up being unhappy with your investment in wind power. If you say you want to make "a lot" of electricity, wind energy experts will tell you that the system will cost "a lot" of money. If you say you want to make 150 KWH per month, your renewable energy installer will be able to suggest a few turbine options and give you a cost in dollars, or at least an informed estimate.

Efficiency Next

Once you know how many KWH you use or expect to use, you could proceed to "Go" and start shopping for wind-electric system components. But your time and money will be better spent by first focusing on energy efficiency. Typical Americans can reduce their home's energy use by 20% to 50% (or more) by using more efficient lighting and appliances, defeating phantom loads, and simply by being determined to use less.

interpreting wind turbine specifications

The Specifications table on pages 32 and 33 shows basic specs for home-scale wind turbines available and supported in North America. Understanding the specifications will help you make intelligent choices when it's time to buy your turbine.

Manufacturer/importer contact information is included in the Access section at the end of this article. In some cases, the wind turbines are either remanufactured or imported. For imports, the North American contact is listed.

Swept area of the rotor is the area in square feet of the circle "swept" by the blades. This is the "wind collector" area and, besides your average wind speed, is the single largest factor influencing turbine output. A larger rotor will give you more energy, all other things being equal (and they usually are).

Rotor diameter is directly related to swept area. It would be handy to use the square footage of the rotor as an identifier for turbines. More often we use diameter, though it's hard for most people to quickly determine swept area from rotor diameter figures. Although the difference between a turbine with an 8-foot-diameter and one with a 10-foot-diameter might not seem large, it represents a 58% increase in collector size, with a proportional increase in energy output.

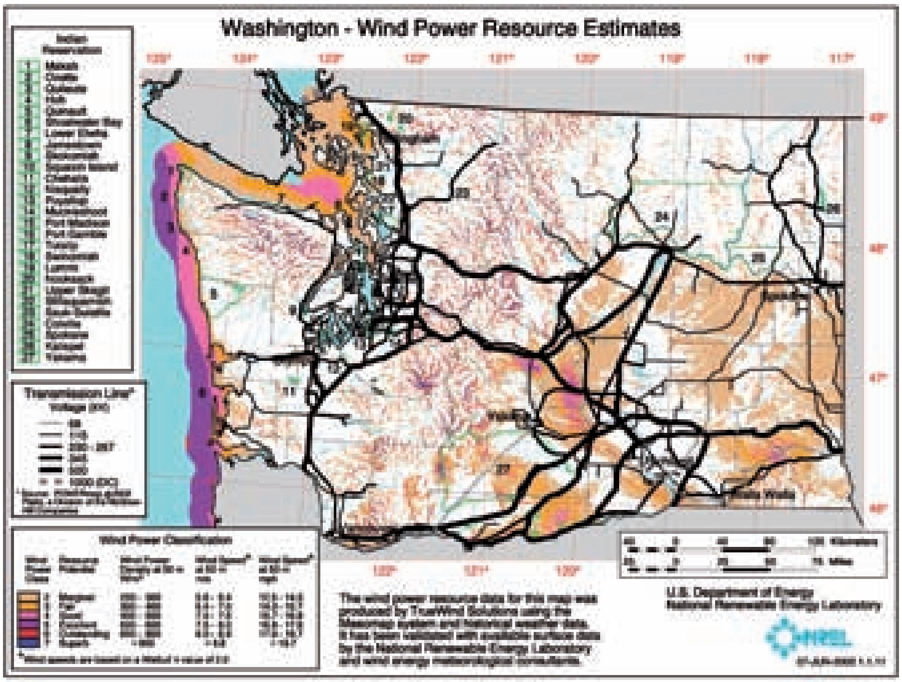
Tower-top weight is necessary to know when choosing your tower, along with swept area. A heavier turbine also may be an indication of a more rugged machine. Though weight itself doesn't necessarily translate into turbine longevity, a rugged turbine that holds up over the long haul often results from a heavier machine.

Annual energy output (AEO) at 8 through 13 mph gives you some general numbers to match to your site's average wind speed and energy needs. Note that all AEOs provided in the table are either from the manufacturer or derived from manufacturer's data. Your turbine's performance on your site may vary, *sometimes significantly*. Be conservative, by choosing the next larger turbine when you're not sure of your exact energy use or if the exact size turbine you need is not available. Also, AEOs apply to locations from sea level to 1,000 feet in elevation and must be adjusted for lower air density at higher altitudes. Your installer or turbine manufacturer can help you crunch these numbers.

Rpm is the blade revolution speed at the turbine's rated output and relates to two factors in wind generators: durability and sound production. A slower rotor speed will generally mean a longer-lasting turbine—less wear and tear on the rotating parts. It also usually means a quieter turbine. Note that lower rpm does not mean lower production, nor does higher rpm mean higher production. In both cases, the alternator is matched to the rotor speed to get as much energy out of the wind as possible.

Governing system describes the method the turbine uses to shed excess energy in high winds to protect the turbine from overspeed. Some turbines tilt, or "furl," the rotor directly up or to the side, while others furl at an angle. Still others use blade pitch control, turning the blades out of their optimum aerodynamic angle, so that they don't capture as much energy. Blade pitching more reliably protects the wind generator. Machines that have this

wind resources map



Reducing your electrical loads will reduce the cost of your system considerably. A smaller wind generator will be needed, and that means you won't need as stout of a tower. The family of an acquaintance recently reduced their electric bill by about 50%—just by using compact fluorescent bulbs and changing their habits. The $60 per month they are saving is going into the kids' college fund—and the youngest has become a real "turn the lights off" fanatic since she saw the savings. They had been using 700 KWH per month, and they're now down to 350 KWH. At an 11 mph average annual wind speed, they just reduced their turbine needs from an Eoltec 6 KW at $25,200 to an ARE 110 at $11,500, a savings of nearly $14,000—plus the savings from the lighter tower needed for the smaller turbine. A smaller battery bank (if batteries are used) may also be in order. All the way down the line, implementing energy-efficiency measures will reduce the size and cost of your wind-electric system.

Resource Analysis

While you're doing the energy-use groundwork, start assessing your wind resource. Home wind-electric systems rarely justify a full-scale wind resource assessment with wind datalogging and analysis, but you must at least get a general idea of the amount of "fuel" you have available before you start reaching for your wallet. It's a little too common to hear of people spending thousands of dollars on a wind-electric system only to discover that reality didn't

specs continued

feature cost more (due to more moving parts and complexity) than machines that furl.

Governing wind speed is the point at which the turbine starts governing. A low governing speed shows that the turbine designer was conservative—more interested in long-term operation than squeezing out a bit more energy from infrequent high winds.

Shutdown mechanism is different from governing, and refers to a method to stop the turbine for service, in an emergency, or when you just don't need the energy. Many small turbines have no mechanical means to shut them down. Instead, they rely on dynamic braking (electrical shorting of the windings), which does not always work, especially when needed in higher winds. Mechanical brakes are usually more reliable than dynamic braking. Generally, more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms.

Batteryless grid-tie tells you whether the turbine is available in this configuration, normally the most cost-effective choice. All battery-charging turbines can be grid-tied via a battery-based inverter designed to synchronize its output with the utility grid, if you're determined to have protection from utility outages. But this approach will incur inefficiencies, losses, and additional cost.

Battery voltages are listed for battery-charging turbines, so you can choose the right turbine voltage for your battery bank. Most modern whole-house battery-based RE systems today use a 48 V battery bank (with an inverter to supply the house with 120 or 240 VAC).

Controls included are what you get when you buy the turbine—whether it includes a controller, a dump load, and metering. These components can be expensive, so don't forget to add them into your calculations if they are not included.

Cost is for the turbine and any included controls, in U.S. dollars. This is only one component in the system, and usually not the most expensive one. A tower, batteries, and inverter each can easily exceed the turbine cost. Note that the EW 15, V-15, V-17, and PGE turbines also include tower, wiring, all installation materials, and labor costs.

Warranty is an indication of the manufacturer's confidence in the machine, or is set to meet the requirements for incentive programs in states such as California. Find out what is covered—usually it's equipment only, and not the costs of replacement labor, which can be significant. Several of the manufacturers that offer shorter than five-year warranties will extend the warranties for an additional cost.

What we're not listing is rated or peak power. That data is close to meaningless and a distracting marketing ploy. One cannot accurately predict annual energy output (which is what you want to know) from peak power, since two machines with similar peak power can give very different energy outputs.

support their unscientific analysis that "it's always very windy."

The ideal situation is to have several years of wind data from your site, at the proposed turbine height. But small turbine buyers rarely do this, and for good reasons. Installing a tower and wind datalogging system of this sort might cost half as much as the wind-electric system, as well as delay the project. The going rate for such a monitoring project is about $15,000. More often, if any wind measurement is done, it is of shorter duration and at a lower height. Taking this data and extrapolating to turbine height, while comparing it to data from nearby monitoring sites, might give you a reasonable guesstimate of what to expect. However, this kind of analysis is more complicated than it appears, and is a good place to seek a wind expert's guidance.

The best wind resource data presently available for most states is the high-quality wind maps available on the Wind Powering America Web site (see Access). The few states without wind

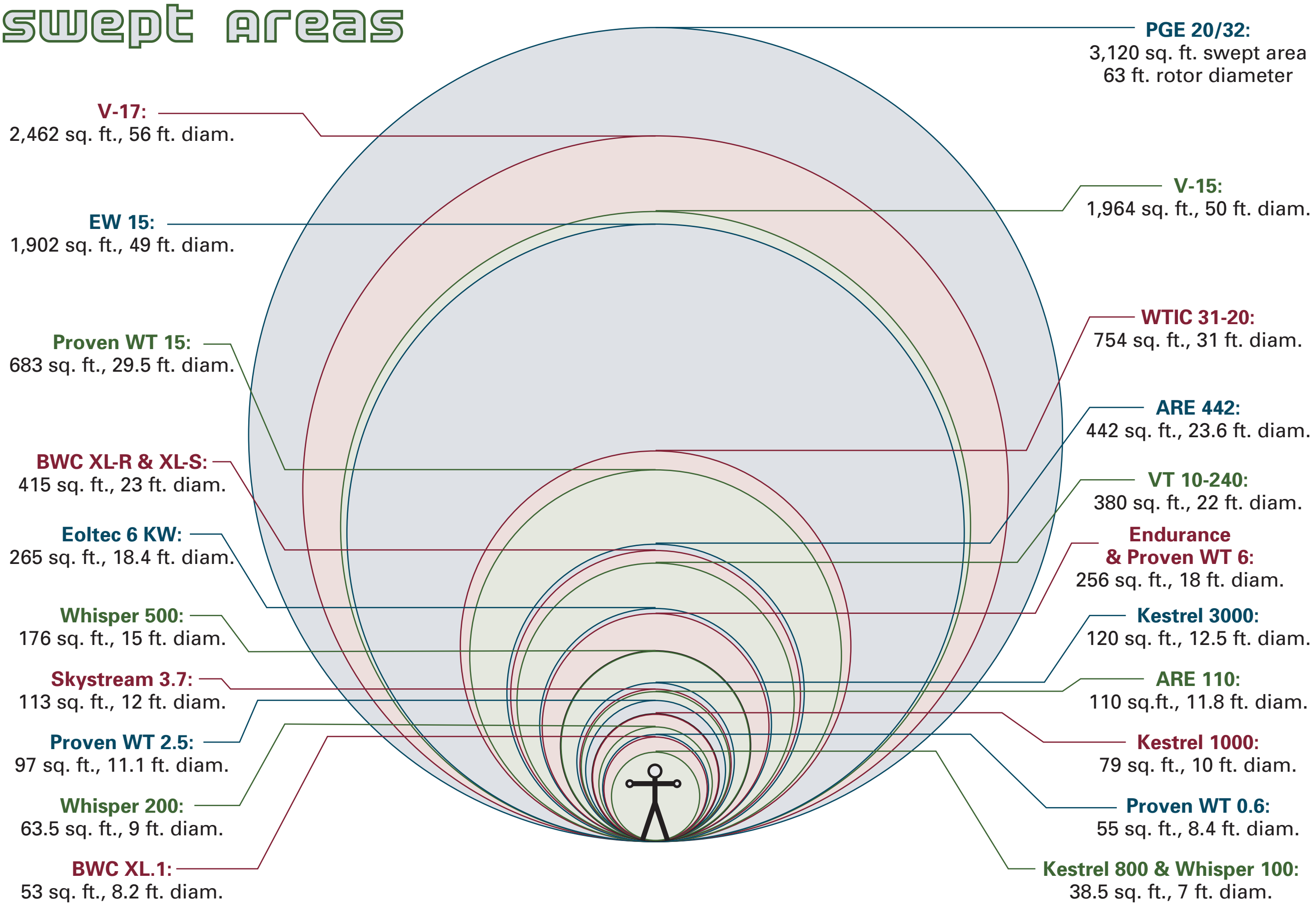
energy expectations

As noted elsewhere in this article, we are not including power (watt) ratings for the wind turbines, since this number is primarily a marketing point, and a confusing one at best. We have included annual energy (kilowatt-hour) outputs from the manufacturers for a range of wind speeds. But how accurate are these? In preparing this article, some manufacturers expressed concern about the possibility of inflated figures, and were worried that their conservative numbers wouldn't compare well.

We considered publishing only energy estimates based on the formulas (referenced in the articles in Access) developed by Jim Green at NREL and Hugh Piggott in Scotland. Though the formulas give more conservative numbers, comparing Green's with the manufacturers' numbers shows wild variation—differences ranged from 1% to 52%! We don't really know which is more accurate, and the formulas make no account for variations in efficiency of different turbines, or for performance variations at different wind speeds. Piggott states that these formulas yield numbers that may be off either way by 20% or more.

What's a wind turbine buyer to do? Until we have a national standard and independent standardized testing of home-scale wind turbines, you must look at the manufacturers' numbers with great skepticism. Apply the formulas to the turbines you're considering (see Access). Ask the manufacturer where their numbers come from. Search the Internet and elsewhere for end users, dealers, and others who have data. The scattered real-world data that is available often varies widely from manufacturers' numbers, a fact that should ring alarm bells in your mind. In the end, you may decide to just buy a larger turbine—being pleasantly surprised with more energy than you expected is much preferred to being disappointed with your investment.

swept areas



specifications for common wind turbines

	Kestrel 800	Whisper 100	BWC XL.1	Proven WT 0.6	Whisper 200	Kestrel 1000	Proven WT 2.5	ARE 110	Skystream 3.7	Kestrel 3000	Whisper 500
Manufacturer / importer[a]	Kestrel	SWWP	Bergey	Proven	SWWP	Kestrel	Proven	ARE	SWWP	Kestrel	SWWP
Swept area (sq. ft.)	38.5	38.5	53.0	55.0	63.5	79.0	97.0	110.0	113.0	120.0	176.0
Rotor diameter (ft.)	7.0	7.0	8.2	8.4	9.0	10.0	11.1	11.8	12.0	12.5	15.0
Tower-top weight (lbs.)	55	47	75	154	65	132	419	315	170	331	155

Annual Energy Output (KWH) at Average Wind Speed (Estimated by Manufacturer)

	Kestrel 800	Whisper 100	BWC XL.1	Proven WT 0.6	Whisper 200	Kestrel 1000	Proven WT 2.5	ARE 110	Skystream 3.7	Kestrel 3000	Whisper 500
8 mph	480	360	660	~504	720	900	~2,004	1,620	1,200	1,560	2,040
9 mph	780	540	1,020	~792	1,080	1,080	~2,472	2,316	2,040	2,100	2,760
10 mph	960	780	1,380	~996	1,500	1,560	~3,516	3,144	2,880	2,760	3,960
11 mph	1,320	960	1,800	~1,356	1,920	1,920	~3,996	4,068	3,720	3,900	4,920
12 mph	1,500	1,200	2,256	~1,488	2,280	2,520	~5,004	5,040	4,560	4,500	6,456
13 mph	1,920	1,500	2,640	~1,752	2,700	2,580	~5,580	6,060	5,400	5,760	7,440
Rpm at rated output	1,000	1,200	450	500	1,100	650	300	340	325	500	900–1,000
Governing system	Blade pitching	Side furling	Side furling	Blade pitching	Side furling	Blade pitching	Blade pitching	Dynamic brake, side furling	Dynamic brake	Blade pitching	Side furling
Governing wind speed (mph)	27	28	29	27	26	21	27	25	30	28	27
Shutdown mechanism	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Disc & dynamic brakes	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake
Batteryless grid-tie	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Battery voltages available	12, 24, 48	12, 24, 36, 48	24	12, 24, 48	12, 24, 36, 48	12, 24, 48	24, 48	48	No	48	24, 48
Controls included	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes
Cost (battery-based/ batteryless)*	$1,995	$2,475	$2,590	$7,680	$2,995	$2,950	$10,140	$8,870 / $11,500	$5,400	$8,400 / Call	$7,675 / $12,125
Warranty (years)	5	5	5	2[b]	5	5	2[b]	5	5	5	5

[a] See Access for contact info. [b] Extended warranty available [c] Price includes tower & complete installation [d] Inverterless grid-tie, includes 105-ft. tower
*Cost estimates based on 10/2007 pricing

maps have *some* data available, from airports, universities, wind energy users, weather hobbyists, or government agencies. Look around to see what you can find there, but do track down where the data came from, since some data may come from monitoring equipment that is not installed high enough in the wind to produce reliable and useful information.

More subjective analytic methods can be used, though they should be used with a great deal of caution. Long-time residents can give you impressions about how windy it is and has been—apply lots of salt. Your own observations on your property can be better than nothing. And the way vegetation is deformed by the wind can be an indicator of the presence or lack of a wind resource. There's even a scale that correlates tree deformation with wind speed—the Griggs–Putnam Index.

The goal of all this analysis is to come up with your site's average annual wind speed. You want to know this number at your proposed tower height because it represents the "fuel" available to your wind generator to turn into electricity. This is most often in the 8 to 13 mph range for home-scale systems. Sites with an average below 8 mph may not have enough wind energy to justify the investment in a system, unless the site is off-grid and you're replacing engine generator fuel.

Selecting Your Turbine

Now that you know your needs and you've determined your resource, it's time to go shopping. Any wind turbine manufacturer worth buying from can supply you with annual energy output (AEO) numbers for various average wind speeds. You simply need to choose a turbine that will produce the amount of energy you need with your wind resource. If you determine that you want to generate 2,100 KWH per year in your 11 mph average wind regime, check out the manufacturers' output predictions to see what's available.

For off-grid applications, you'll need to consider seasonal energy usage. If your windiest season matches up with your heaviest use of energy, you'll make the most of your system. But in other cases, you may need to oversize your wind turbine to cover the seasonal load variation. And with off-grid systems, you will almost certainly need a second source of energy, like solar electricity.

	Proven WT 6	Endurance	Eoltec 6 KW	VT 10-240	BWC XL-R	BWC XL-S	ARE 442	Proven WT 15[e]	WTIC 31-20	EW 15[f]	V-15[f]	V-17[f]	PGE 20/32[f]
	Proven	EWP	Eoltec	Ventera	Bergey	Bergey	ARE	Proven	WTIC	Entegrity	EMS	Halus	Energie PGE
	254.0	254.0	265.0	380.0	415.0	415.0	442.0	683.0	754.0	1,902.0	1,964.0	2,462.0	3,120.0
	18.0	18.0	18.4	22.0	23.0	23.0	23.6	29.5	31.0	49.0	50.0	56.0	63.0
	1,102	600	445	500	1,050	1,050	1,350	2,425	2,500	5,340	9,920	14,065	7,200
	~5,004	1,843	3,528	3,720	4,080	2,880	7,476	~10,980	9,828	N/A	N/A	N/A	N/A
	~6,768	3,091	4,908	5,520	6,000	4,440	10,440	~16,908	13,920	34,000	38,000	N/A	53,280
	~8,004	4,587	6,816	7,680	7,920	6,240	14,052	~22,320	19,728	50,000	43,000	62,520	64,920
	~11,004	6,268	8,544	10,200	10,560	8,400	17,640	~28,080	25,704	68,000	58,000	81,360	82,296
	~12,996	8,068	10,656	12,960	13,080	10,800	21,972	~33,360	32,292	88,000	64,000	101,640	90,000
	~15,000	9,920	12,756	16,080	15,840	13,560	25,584	~38,880	39,288	110,000	80,000	122,880	107,796
	200	206	245	280	300	300	140	150	175	62	52	45 to 50	32
	Blade pitching	Stall regulated airfoil	Blade pitching	Blade tip pitching	Side furling	Side furling	Dynamic brake, side furling	Blade pitching	Blade pitching, side furling	Stall regulated airfoil	Stall regulated airfoil	Stall regulated airfoil	Electrically stalled, blade pitch
	27	26	26	29	36	36	25	27	25.5	N/A	N/A	N/A	N/A
	Disc & dynamic brakes	Disc brake	Optional blade pitching	Dynamic brake	Crank out tail	Crank out tail	Dynamic brake	Disc, dynamic brakes	Disc brake	Tip brake, electro-dynamic brake	Motor yaw, disc brake	Motor yaw, disc brake	Disc brake
	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	48	No	No	No	48, 120, 240	No	No	48	No	No	No	No	No
	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
	$21,550	$35,000[d]	$25,200	$14,500	$22,900	$27,900	$36,000	$41,350	$33,900	$170,000[c]	$140,000[c]	$180,000[c]	$170,000[c]
	2[b]	5	5	5	5	5	5	2[b]	1[b]	5	1[b]	1[b]	2[b]

[e] Not yet available in U.S. [f] Single-phase and three-phase utility configurations may be available; energy outputs may vary with phase configuration

You'll find only a couple dozen selections in the small wind turbine market, and in any given size range, just one or a few choices. Other parameters may further limit your options, such as system voltage, batteryless versus battery-based machines, and machine durability. If you have to choose between two turbines that straddle your target energy need, buy the larger one—it's much better to end up with more energy than less.

But don't just think about the present. Never buy a turbine solely on its up-front cost, but rather on what it will cost you over the long haul—in money, time, and aggravation. Wind-electric systems are the toughest renewable energy systems to maintain, with the highest failure rate. Why? Because wind turbines live in a brutal environment atop 80- to 120-foot (or so) towers not readily accessible if you don't climb, or if it's minus 30°F outside with a 30 mph wind.

Avoid these pains by buying the highest-quality system you can afford. Unlike a car, you won't be able to drive your "bargain" down to the dealer for warranty repair. You'll have to pay someone to climb your tower and fix it, or do it yourself—neither is cheap nor easy.

Balance of Systems

A wind turbine is just one part of a *system*. You'll need other components to actually make electricity. Though the wind generator is a critical component to buy well, you should give similar attention to the other parts of the system.

Your tower design will be determined by the weight and swept area of your wind generator, the specifics of your site, and your preferences and budget. (See the tower article referenced in Access for more information.) The best suppliers of wind generators also supply towers, knowing what is appropriate for their machines.

System electronics include charge controllers, inverters, and metering. Sometimes these are included with the turbine, and other times you have some choices—depending on whether your home is off-grid or on, battery-based or batteryless. Make sure you understand the options, as these components must be matched to the turbine and to other parts of your system.

Batteries are a big subject, and if you intend to use them in your system, you should educate yourself. Off-grid users must carefully consider how much storage they want, and whether they will use backup or other energy sources like PV.

caveat emptor

If you cruise the Internet, you may find a turbine that interests you, but is not listed in this article. This article includes only the turbines that we consider reliable at the present time, manufactured or imported, and supported by reputable companies in the small wind industry. There are turbines in development that are not quite ready for production but may become available in the future. There are attractively priced imports that may eventually be considered viable choices. And there is a lot of equipment that is just not ready for prime time yet. Stay tuned—they may make it into future updates.

On-grid users who want utility outage backup must analyze the critical loads they'll want to power. We recommend that you work with an experienced supplier who can help you make the important decisions of battery type, size, and system design and installation.

Other components in a system include wiring, disconnects, overcurrent protection, and grounding. These are issues that require electrical expertise and experience. Either hire a qualified person or take the time to get enough education to do a safe, code-compliant job.

Do It Right!

If you're a novice at electrical and mechanical installations, don't even consider taking on a wind turbine installation yourself. Because of gravity and the tower heights involved, this is serious business—fraught with potential danger to life and limb, as well as the opportunity to make poor design and installation decisions that could affect performance and safety over the life of the system. If you have any doubt about your abilities, hire a professional. Think of this system like an automobile. Most of us don't even do our own auto maintenance; much less would we would even consider designing and building a vehicle. Wind electricity is not an easy DIY project, and may never be, since it requires tall towers to get the turbine up into its "fuel."

Wind-electric systems are not easy, simple, cheap, or perfectly reliable. But if you do your homework, buy quality equipment, and get the help you need, you can end up with a long-lasting and satisfying system. Thousands of families have done just that, and they look up regularly to see their turbine spinning, making electricity from the wind!

Access

Ian Woofenden (ian.woofenden@homepower.com) has been living with wind electricity since the early 1980s, and teaches, consults, and writes about wind energy from a real-world perspective. He is a supporter of *successful* wind-electric systems, steering people away from hype and unrealistic expectations.

Mick Sagrillo consults (currently as the wind technology specialist for Wisconsin's Focus on Energy), teaches, and writes about small wind based on almost 30 years' experience installing and operating nearly all the turbines covered in this article. He reminds folks that it's not about "cheap," but about reliable renewably generated electricity.

Further Reading:

"Wind Turbine Buyer's Guide," Mick Sagrillo & Ian Woofenden, *HP118*

"Anatomy of a Wind Turbine," Ian Woofenden & Hugh Piggott, *HP116*

"Wind Generator Tower Basics," Ian Woofenden, *HP105*

"Estimating Wind Energy," Hugh Piggott, *HP102*

Other Resources:

Explanation of Jim Green's AEO formula can be found at www.nrel.gov/docs/fy07osti/40925.pdf on page 9

Wind Powering America • www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp • Wind resource maps

For more detailed information on the topics raised in this article, see the technical appendix, available at www.homepower.com/promisedfiles

Wind Turbine Manufacturers/Importers:

ARE, Abundant Renewable Energy • www.abundantre.com

Bergey, Bergey Windpower • www.bergey.com

EMS, Remanufactured by Energy Maintenance Systems • www.energyms.com

Endurance, Endurance Wind Power • www.endurancewindpower.com

Entegrity, Entegrity Wind Systems Inc. • www.entegritywind.com

Eoltec, Pine Ridge Products • www.pineridgeproducts.com; Solacity • www.solacity.com

EWP, Endurance Wind Power • www.endurancewindpower.com

Halus, Remanufactured by Halus Power Systems • www.halus.com

Kestrel, Imported by DC Power Systems • www.dcpower-systems.com

PGE, Énergie PGE • www.energiepge.com

Proven, Imported by Alaska RE • www.remotepowerinc.com; Lake Michigan Wind & Sun • www.windandsun.com; Solar Wind Works • www.solarwindworks.com

SWWP, Southwest Windpower • www.windenergy.com

Ventera • www.venteraenergy.cm

WTIC, Wind Turbine Industries Corp. • www.windturbine.net

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Courtesy Scott Franklin; opposite page: Topher Donahue

Solarscapes
A NEW FACE FOR PV

by Topher Donahue

If you count yourself among the people who love the idea of making their own clean energy, but balk at the idea of planting a pole mount in the middle of your backyard or covering your historic home's rooftop with high-tech PV modules, this fresh design strategy offers a solution.

The concept—aptly dubbed "solarscaping"—is a new take on building integrated photovoltaic (BIPV) systems. Unlike traditional BIPV systems that are designed into a structure from the blueprint phase, solarscapes work with both new and existing structures and can minimize the aesthetic concerns of adding PV to your home.

"Solarscaping is another avenue to facilitate our mission of helping people choose solar power," says Scott Franklin, president of Lighthousesolar, a solar system design and installation company based in Boulder, Colorado. "The more options we can provide our customers, the greater chance we can meet their needs. These designs allow customers to get more function from their PV investment."

Though the idea of integrating PV into architectural structures is not new, Lighthousesolar is one of the first to offer a package option that also can be custom-fit to an application. Installation of a solarscape involves minimal time at the site. Structures are customized in the company's workshop in Boulder, delivered to the installation site in several large pieces, and assembled in one or two days. So far, the company has integrated PV systems into awnings, pergolas, carports, hot tub shades, and gazebos, and the potential is limitless, Franklin says. Fences, fountains, greenhouses, archways, and sunrooms are all good candidates, he adds.

WHAT'S IN A SOLARSCAPE?

A solarscape features two elements. The first is a wooden or steel custom-made frame that is painted, trimmed, or finished to complement the home and landscaping.

The second component—the HIT (heterojunction with intrinsic thin layer) bifacial modules made by Sanyo—is key to the design's sleek look and increased energy production. These double-sided modules—which harvest solar energy from both the front and back faces—maximize power within a fixed amount of space. In an ideal setting, bifacial panels can be the most cost-effective modules based on dollars per watt.

Instead of the standard opaque module backsheet, Sanyo Double modules have glass-on-glass construction. Clear glass layers on both sides of the photovoltaic cells allow additional reflected solar energy to be captured from the back side of the module. The glass-on-glass construction adds aesthetic value as well by allowing some light to filter through the array. The subtle octagonal design of the silicon cells projects a soft light-and-shadow pattern on the surfaces beneath the array—similar to light filtering through the leaves of a large-leafed tree. Enough light passes through the modules to allow plants to grow underneath the array canopy while providing adequate protection for those seeking respite from the sun.

Behind Bifacial

Introduced in 1976, bifacial PV technology was most widely known for its use on spacecraft, including the International Space Station. Designed in response to the challenges of keeping monofacial modules oriented to the sun, bifacial arrays allow spacecraft more orientation options when orbiting the Earth. As an added bonus, the rear side of bifacial arrays can convert reflective radiation from the atmosphere into extra energy.

Over the past decade, bifacial PV technology has found its place on Earth, incorporated mainly in commercial applications such as awnings, street signs, bus stop shelters, and sound barriers. Recent innovations in optic technology have reduced the amount of silicon needed in a PV module and brought the cost of bifacial technology down to an earthly level, with a cost per watt about 20% higher than comparable single-sided modules. A lower price tag and opportunity for greater energy production has made bifacial PV a practical component for BIPV systems, as well as for use in systems that can earn performance-based incentives and renewable energy credits.

Courtesy Scott Franklin

Unlike monofacial (single-sided) PV modules, the back side of a bifacial module generates power from light that is reflected off surrounding surfaces. Radiation from reflective surfaces—light-colored wood, metal roofing, concrete, white gravel, snow, or water—can increase the energy yield beyond the manufacturer's standard test conditions (STC) output ratings. Sanyo estimates that the bifacial construction adds approximately 10% to module output when compared to a single-sided Sanyo HIT module in an angled installation, or as much as 34% in a vertically oriented installation.

"We know the bifacial panels have a strong power advantage, but it's hard to quantify because each installation has different characteristics," Franklin says. "Even Sanyo is hesitant to predict output because the numbers can vary significantly based on installation specifics."

Based on reports he has received from the field, Benjamin Collinwood, Sanyo's solar market development manager, estimates that typical production increases will be between 15% and 20%. He says that system results vary, depending upon individual site characteristics such as system design, location, and site albedo.

SOLARSCAPING SOLUTIONS

Beyond the reflective radiation advantage, solarscapes can offer a much-needed solution for properties without a shade-free location for a roof- or ground-mounted array. Likewise, many buildings have less-than-optimal orientations for solar energy collection. Solarscaping can provide new and attractive options for array siting in many locations.

Homeowner Neil Cannon wanted to integrate PV into his newly built house in Eldorado Springs, Colorado, but he did not want to compromise the home's historic-looking design. Because tall trees shaded areas closer to the house, he needed a freestanding unit that could be located more than 100 feet away. Adding to the challenge, the structure had to be tall enough to avoid the shade of nearby trees.

Above: A solar-electric carport.

Below: Monofacial modules integrated into an awning serve a dual purpose: making electricity and providing shade for the windows.

Topher Donahue

Functional Design

Tucked in the Rocky Mountains at 8,236 feet above sea level, Scott Franklin's home occupies an idyllic spot in small-town Nederland, Colorado. Like some homes, its site is far from ideal for accommodating a roof-mounted solar installation. The house's solar access was limited by a northwest-southeast roofline and blocked by neighbors' trees. By building a detached office with an east-west orientation two years ago, Franklin created room for a 1.4 KW system.

Wanting to offset more of his family's household electricity consumption, Franklin explored other options. Knowing that a roof-mounted system on the home would be ineffective and a ground-mounted system would eat into the children's play area, he looked for a novel way to integrate an additional PV system.

"We'd lived in our home for six years and barely used our back, south-facing deck. We couldn't sit out there on a sunny day because it was either too bright or too hot," Franklin says. "An awning seemed like a natural solution for both problems."

So last spring, Franklin and the Lighthousesolar crew installed the company's first-built Power Awning—a custom-welded, 10- by 21-foot steel frame that incorporates fourteen 190 W bifacial modules—over the existing deck. The crew crafted the steel frame in the workshop and assembled the awning at the home over three days.

The picnic table beneath the awning has become the Franklins' favorite spot for both morning coffee and evening barbecues. During the mountain winters, some sunlight can pass through the array, preventing the dark, cold shadow created by a conventional awning and bringing some light into the home's interior.

Although the dark deck planks limit how much light is reflected to the underside of the array, the energy production of the awning's bifacial panels has exceeded Franklin's original expectations. On clear summer days, the net production from the Power Awning and the small roof-mounted system on the office is enough to spin the utility meter backward.

"The nicest thing is that the awning created a usable space for the family. Now we can sit out there and enjoy the view of the mountains," Franklin says. "The added bonus is that our electric bill made it down to zero."

The Power Awning cost about the same as a ground-mounted system but saved the crew from the time-consuming and backbreaking work of drilling through solid granite and running cables hundreds of feet to the inverter. A similarly sized roof-mounted system would have cost about 30% less than the Power Awning. The increased energy production of the bifacial modules helps to offset a portion of the higher cost. After federal and state rebates, the 2.66 KW awning system cost about $14,000.

Topher Donahue

A solar-electric awning over the Franklins' backyard deck provides additional energy generation and a comfortable space for outdoor activities.

The solution? A customized double carport roofed with 4.5 kilowatts (KW) of PV modules to meet 100% of the household's electricity needs, and several evacuated tube collectors for solar water heating. To keep with the look and feel of the home, the sides of the structure will be finished with rough-sawn lumber that resembles old barn siding.

"We're really charged about the idea," Cannon says. "It was really important that the structure be congruous with the landscape and the home, and this is a great compromise. Up close you'll be able to see the high-tech gear, but from far off in the distance, it'll blend in nicely. "

Solarscapes offer several access and maintenance advantages over typical roof-mounted PV systems. The absence of roof-mounted arrays, for example, means roof maintenance and remodeling can be done without dismantling the solar-electric infrastructure. Increased airflow around the array will keep module operating temperatures lower and result in increased energy harvest.

PUTTING A SHINE ON PV

A prototype of Lighthousesolar's signature Power Awning at Franklin's home has won over several homeowners (see Functional Design sidebar). All it took was one look at the awning's sleek design—a black steel frame inset with double-sided PV modules—to sell Marcus Luscher on the concept.

"When you first look at the awning, you don't even notice that it's a PV system. Only when you actually sit beneath it and see the PV panels do you realize that the awning is also generating power," Luscher says. "It's an attractive piece of architecture that is multifunctional." He plans to add a power awning above the deck at his home in Nederland, Colorado. The solarscape system will supplement his current nine-module PV system and help offset the electricity consumption of his newly purchased hot tub.

DOUBLE-SIDED SOLUTIONS

While bifacial PV awnings and carports are common in commercial BIPV installations, the concept is relatively new to residential projects. But solarscaping is gaining traction in home-scale installations because of potential aesthetic and versatility advantages when compared to traditional roof- or ground-mounted arrays.

Currently, Lighthousesolar delivers and installs customized units in Colorado and Texas, but the company has plans to expand its installation territory. Lumos offers prefabricated solarscape kits to building contractors nationwide.

Several module manufacturers have partially transparent glass-on-glass modules that will soon be headed toward the U.S. building market. In the years ahead, these PV modules will undoubtedly be used in both prefab and custom residential structures, creating spaces that are as productive as they are attractive.

ACCESS

Topher Donahue was born in a cabin without running water in Wild Basin, near Colorado's Rocky Mountain National Park. He is now helping his mother upgrade the cabin to photovoltaic power. His business, Alpinecreative (www.alpinecreative.com), based in Nederland, Colorado, provides photography and writing for the outdoor recreation and alternative energy industries.

Lighthousesolar • 303-638-4562 • www.lighthousesolar.us • Power Awning installer

Lumos • 303-449-2394 • www.lumossolar.com • Power Awning, double carport, and hot-tub shade manufacturer

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Born to Be Wired

by Kelly Davidson

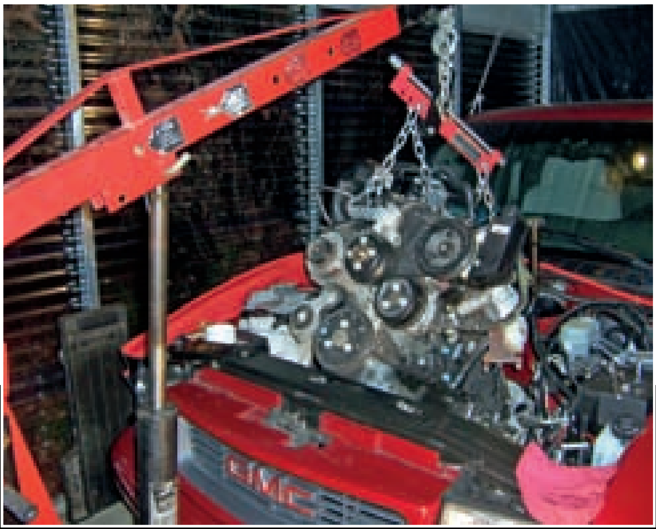
Randy Richmond's full-electric-powered GMC Sonoma pickup, converted using a commercial kit.

For nearly a decade, engineer Randy Richmond explored the idea of owning an electric vehicle (EV). He scoped out the latest technology at renewable energy fairs and read countless blogs, articles, and Web sites devoted to the topic. His interest even grew into a side business with his family—RightHand Engineering, a designer and seller of software tools that monitor RE and EV systems.

Although he'd hoped to buy a new factory-made electric vehicle, that dream died when most leading manufacturers stopped production in the late 1990s. When gasoline prices reached more than $3 per gallon, he wondered if gas rationing would soon follow—a repetition of the 1973 oil crisis. Imagining people lined up by the hundreds to fill their fuel tanks was the final push he needed.

"I realized that the time had come, and I had to do it on my own. There was no use waiting for the auto industry because I'd wait forever," he says. "I no longer wanted to contribute to the problems in the Middle East, and I wanted a vehicle more consistent with my renewable energy lifestyle and business."

Out with the internal combustion engine.



Lots of room in the engine compartment.

In April 2006, Richmond started running the numbers and asking lots of questions. Before committing to an EV conversion, he considered the "easier" alternatives, such as buying a specialized EV, like the Myers Motors Sparrow/Nmg or the ZAP Xebra, or buying a used, factory-produced model like the Toyota RAV4 EV, Chrysler EPIC minivan, GM S-10 EV pickup, or Ford Ranger EV pickup. Either too small, too slow, too expensive, or too hard to find, none of them were a good match for his needs.

Devising a Plan

Richmond found an invaluable resource in the Electric Auto Association, a nonprofit organization that promotes the advancement and widespread adoption of EVs. Through the Web site, he connected with other electric car enthusiasts, who were happy to answer his countless questions. With the guidance of their triumphs and failures, he developed his plan of action, and by May, he was ready.

Even with an electrical engineering degree from the University of Washington and a longtime interest in electric vehicles, Richmond considered hiring a private EV enthusiast or commercial EV conversion company to do the conversion.

"If you cannot do standard mechanical repairs to your vehicle, basic electrical wiring around your home, or remove an engine, you should not do the conversion yourself," he says. "Don't hesitate to pay someone to do it, or buy a vehicle that's already converted. Working on conversions isn't for everyone."

Ultimately, after evaluating his electrical and mechanical skills, Richmond felt comfortable moving forward with a "do-it-yourself" EV conversion. He did, however, recognize his limitations with metal fabrication and welding, and formulated his plan accordingly.

From the get-go, he knew a piecemeal approach—buying the parts individually—might be too complicated. Customizing adapters and mounts went beyond his skill level. He decided that a conversion kit—which comes equipped with most of the mechanical parts—would best suit his needs and abilities.

Randy Richmond takes his electric truck to auto events to help spread the word on EV practicality and performance.

Choosing a Vehicle

Richmond says that establishing realistic needs is one of the first and most important steps in the process of vehicle selection. How far do you need to go each day? How fast do you need to go? What kind of acceleration do you need? How much do you want to be able to haul? What kind of weather will you need to travel in? The answers to these and other questions will determine the vehicle, vendor, and components used for the conversion, as well as the design and EV conversion approaches.

The 100 hp DC motor bolted to the original transmission.

Installing the new electric motor and transmission, with room to spare.

Above the drive motor— six T-145 lead-acid batteries and the control box, mounted to the left of the batteries.

Richmond carefully evaluated his weekly commute: four 18-mile trips along local, rural roads near his home in Woodinville, Washington, and one 40-mile trip to nearby Issaquah with some distance on Interstate 405. The highway driving, though brief, necessitates that the vehicle reach 60 mph. He needed enough horsepower to handle the extra weight of the batteries in the vehicle and get up the hills along his commute. He decided against power-intensive air conditioning and power steering but elected for power brakes and electric heating, given the weight of the vehicle and the cool, rainy conditions in the area. Though the vehicle would be used primarily for commuting, he wanted enough seating for his family.

He knew that a small car or a neighborhood electric vehicle (NEV) would not suit his needs. He quickly turned his attention to pickup trucks. With a convenient place for batteries and the capacity to handle extra weight, small pickup trucks tend to be the easiest to convert. Plus, there is a greater chance of finding a cost-effective and easy-to-use conversion kit, says Richmond, since there are several kits made for pickup trucks.

In the bed—a custom battery box holds eighteen T-145s.

A mechanically sound vehicle is key to a successful conversion. "The vehicle had to be something that I would be happy to drive," he says. "I did not want to invest my time and money into an unsound or unsightly vehicle. I wanted a vehicle that was in good shape and had some longevity."A late-model 2001 GMC Sonoma pickup with an extended cab, five-speed transmission, and fewer than 80,000 miles on its odometer filled the bill.

Getting the Goods

"The EV conversion kit industry is not quite mainstream," Richmond says. "You have to shop around, pick and choose, and be patient."

After some Web research, he decided to purchase the S-10/Sonoma kit from Canadian Electric Vehicles Ltd. Randy Holmquist and his team in British Columbia have more than 12 years of experience with electric vehicles, but it was the responsive customer service and attention to detail that won Richmond over. Unlike some other distributors that just provide raw materials and instructions for fabrication, CanEV prefabricates all the adaptors, mounts, brackets, and boxes—virtually eliminating fabrication from the installation process.

The $10,700 cost of the kit did not include batteries, the controller cooling system, or the battery state-of-charge meter. The controller cooling system—a water circulating pump and miniature radiator—came from EV Source, a distributor based in Logan, Utah.

To save on shipping, Richmond purchased the 1,800 pounds of batteries from Allied Batteries in Seattle. The kit recommended 225 amp-hour (AH) golf cart batteries, but Richmond chose ones with a slightly higher capacity—24 Trojan T-145 (6 V, 260 AH)—to achieve a greater driving range. Richmond's company—RightHand Engineering—supplied the Xantrex Link-10 battery state of charge (SOC) meter.

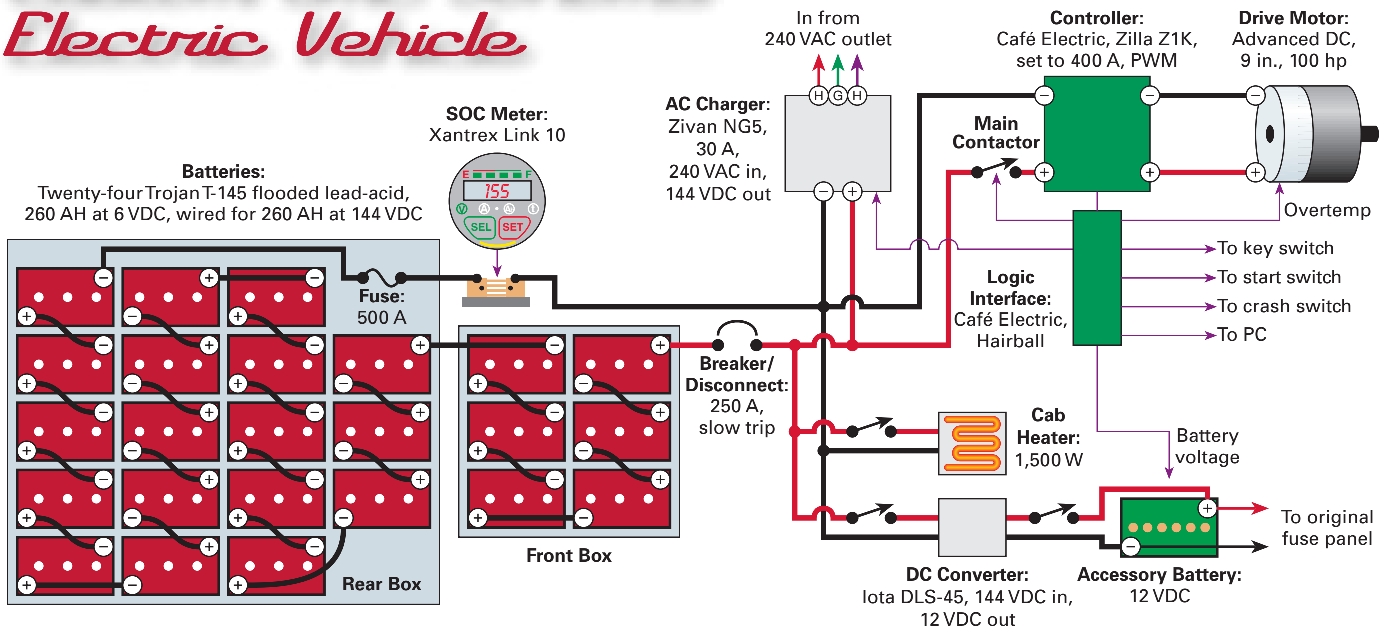
The kit arrived on time with all the parts needed for the conversion—except for the controller and charger, which Richmond decided to customize to his application. By upgrading from a 120-volt charger to a 240-volt charger, he reduced the battery charge time from 12 hours to 4 hours. He swapped out the 300 A Curtis controller included in the CanEV kit for a Café Electric Zilla controller, which offers PC interface capabilities. The Zivan battery charger and Zilla controller took four months to arrive because both manufacturers had a backlog of orders.

Wiring Critical Connections

While waiting for the back-ordered parts to arrive, Richmond wired the control box. As the central hub for the vehicle's wiring, the control box contains all the relays that connect the main battery bank to the vehicle systems. Wiring the box took more than 30 hours.

Although CanEV can pre-wire the main control box, a bonus for those who are less familiar with electrical wiring, Richmond saved money—roughly $1,000—by doing it himself and maintained the flexibility to tweak the kit's electrical design.

Custom GMC Sonoma Electric Vehicle



Giving up the Gas

"As always, deconstructing was far easier than constructing," Richmond says. "This part of the process is straightforward because vehicles are designed to have parts removed and replaced." Over a month of evenings, he removed the ICE components: the exhaust, fuel, engine cooling, and emission control systems. Removing the engine required extra muscle and an engine hoist, which Richmond bought used for $100.

He also removed the air conditioning and power steering systems, which can require a lot of extra energy to operate, and pulled out the transmission to make installing the EV motor easier. (He replaced the power steering with a manual steering box from a 1980s-vintage vehicle of the same make.) In total, deconstructing accounted for a quarter of the entire conversion—about 40 hours.

Going Electric

The most time-intensive part of the conversion was installing the EV components. This took Richmond 110-plus hours spread out over a few months. He says that installing the first component—the electric motor—offers the greatest gratification and the greatest challenge. The centerpiece of the kit—an Advanced DC, 9-inch, 100 peak hp motor—provides power comparable to the truck's original 4-cylinder, 120 hp internal combustion engine (ICE).

It took one long evening for him to install the electric motor on the transmission with the adaptor plate. Though some might have opted to leave the transmission in place and mate the motor under the hood, Richmond had removed the transmission to make connecting the two components easier. The motor mounts on one side of the plate while the transmission mounts on the other side, creating one large, heavy unit.

Placing this cumbersome component where the gas engine used to be was no easy task and warranted an

EV Tech Specs

Overview

Make & Model: 2001 GMC Sonoma, extended cab

Transmission: 5-speed manual

Fuel: 144 VDC, 260 AH, lead-acid batteries (37 KWH)

Mileage: 2 miles per KWH

Fuel Cost: $0.04/mi. or $0.09/KWH

Top Speed: 70 mph

Typical Range: 40 mi. (leaving 20% battery reserve)

Electric Components

Motor: Advanced DC, 9 in., 100 hp peak (30 hp continuous)

Controller: Cafe Electric, Zilla Z1K

AC Charger: Zivan NG5, 30 A, 240 VAC input, 144 VDC output

DC Converter: Iota DLS-45

System performance metering: Xantrex Link 10

Energy Storage

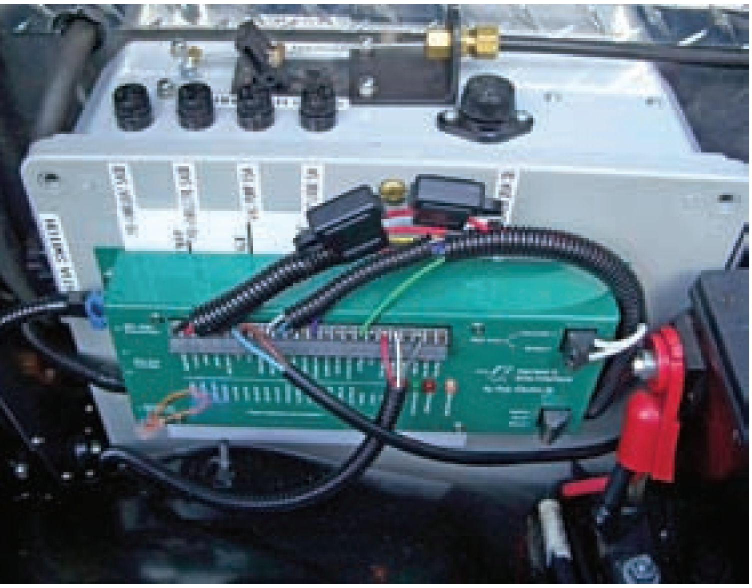
Batteries: Single string of 24 Trojan T-145, 6 VDC nominal, 260 AH at 20-hour rate, flooded lead-acid

Battery Bank: 144 VDC nominal, 260 AH total

Modifications

Vehicle Curb Weight: 4,900 lbs. (original: 3,250 lbs.)

Tires: Goodyear Regatta II, low rolling resistance, 44 psi



The control box, with the logic interface mounted on its cover.

The original gasoline filler cap was replaced by a 240 VAC plug.

evening of its own. "It was an exercise in geometry that required two additional people," Richmond says. "Getting it tilted at just the right angle demands some patience, but we worked it out." Once positioned, the unit is bolted in place using the kit's motor mount. Even with the challenge of installing the motor and transmission as a unit, he had no regrets about his decision to remove the transmission. "It was a trade-off," he says. "Since proper mating is critical, I decided to live with the extra effort to install the combo."

Positioning the Power

Next came the two prefabricated battery enclosures. Besides keeping the batteries securely fastened, the boxes latch to protect against accidental shock. The insulated aluminum boxes also help keep the batteries warm, since cold temperatures result in a temporary reduction in battery capacity.

The kit's electrical design required two battery boxes: one in the bed that holds 18 batteries and one under the hood that holds six more. Because he chose batteries that were slightly taller than the boxes were designed for, he had to remove some metal from the edge of the box that could have made contact with the battery terminals and caused an electrical short. At this point, he secured the box in the bed but held off on installing the under-the-hood box because there was still some conversion work to do in the engine compartment.

Under the Hood

In the space once occupied by the air conditioning unit, Richmond installed a 1,500-watt ceramic heater to provide heat for the cab. Securing the piece required Richmond to fabricate a simple mounting plate from sheet metal—an easy-enough task that suited his metal-working skills.

From there, he worked on the power controller and its cooling system—two of the most important components in the electrical system. The pulse-width-modulated (PWM) power controller regulates the power to the vehicle's drive train by translating the position of the accelerator pedal into power flowing to the electric motor, making the car go.

For every amp that flows to the motor from the controller, 2 watts of waste heat are generated in the controller. At 400 amps, for example, the power controller produces 800 watts of heat. The cooling system circulates water through the controller to cool the electronics, preventing the unit from overheating and causing a thermal shutdown of the Zilla controller.

Outfitting the Cab

With these vital components in place, and after mounting the vacuum pump for the power brakes, the control box, and the remaining battery box above the electric motor, Richmond moved his work from under the hood into the cab. There, he mounted the charger and 45 A DC-DC converter behind the driver's seat. The extended cab allowed enough room for both components, which should not be exposed to the elements. As an added bonus, the charger produces heat while charging. "When it's colder outside, I try to charge the truck right before I leave for work. That way I don't have to run the heater as much, if at all," Richmond says.

The DC-DC converter charges a 12-volt battery (also in the cab) that powers the vehicle's accessories—headlights, windshield wipers, radio, etc. This battery is separate from the traction batteries under the hood and in the bed so that the vehicle can operate standard 12 V accessories independently.

Richmond wrapped up the cab components installation by installing a battery SOC meter—what he considers an "absolute must" for EV newbies who tend to overestimate their battery charge. Much like a gas gauge shows the amount of gas in the tank, the SOC meter shows the amount of energy available in the vehicle's batteries.

Tying up Loose Ends

One of his final tasks—wiring the AC power cabling to the charger—was perhaps the easiest. The AC plug fit perfectly behind the old gasoline filler cap, saving Richmond from enlarging the existing hole.

Last but certainly not least was wiring the three-fold safety system and wiring the batteries to each other. The EV's safety system includes a 500 A fuse in the rear battery box

that opens the circuit if the system shorts; a breaker in the control box that is connected to a knob on the dash board for emergency disconnect; and an inertia switch in the control box that causes the circuit to open and stop the motor in the event of an accident. Wiring the batteries seems fairly straightforward—connecting the positive terminal of one battery to the negative of the next—but tight connections are vital to performance and preventing the connections from overheating and melting the terminals.

Turning the Key

Then came the moment he had anticipated for more than a year—the test drive. "It's a nerve-racking moment. You just hope that everything works and no smoke appears," he recalls.

Rather than running the motor at the full 400 amps, he took gradual steps. Using his laptop connected to the controller's computer interface, he programmed the power controller for 50 amps—barely enough power to move the vehicle. He adjusted the settings eight times, adding 50 amps each time until reaching the maximum, 400 amps. At each increment, he checked all the components and connections for signs of heat and unusual noises.

Much to his surprise, there was nothing wrong—no melting wires, no smoking connections, no mystery noises. The vehicle was road-ready.

"Every increment of the testing built my confidence," Richmond says. "When I actually got up speed and drove it a few miles down the road, I was thrilled with the results. The first thing that struck me was the quiet. When I pulled out, the only sound I heard was the gravel beneath my tires. It was such a cool feeling to drive without putting out any exhaust."

Out with the ICE

Converting an internal combustion engine vehicle to an EV requires getting into the guts of the machine—and removing many parts and pieces. Here's a list of those that went by the wayside in preparation for going electric.

Engine

Emission System

Computer

Air Conditioning System
- Compressor
- Radiator
- Chamber

Air Intake System
- Ducting
- Filter

Exhaust System
- Muffler
- Catalytic converter
- Pipes

Cooling System
- Radiator
- Shrouds
- Hoses
- Fan

Power Steering
- Pump/Reservoir
- PS box
- Hoses
- Fluid cooler

Fuel System
- Gas tank/pump
- Hoses/Lines
- Filter
- Sensor

He noticed only one problem during his inaugural ride: a non-responsive speedometer. Turns out, the signal source for the speedometer—the power train computer—had been part of the gas engine system. So he installed an aftermarket speedometer adapter that takes electrical pulses from the transmission and turns them into signals for the speedometer.

Enjoying the Ride

Where once there was a gas cap, there now is a 240 V, 30 A twist-lock AC plug. A vehicle that once drove 400 miles on a 19-gallon tank of gasoline now drives 40 miles when the EV's batteries are fully charged.

No more gasoline means no more exhaust fumes and none of the maintenance that comes with ICE engines—tune-ups, oil changes, radiator flushes, starter repairs, muffler/exhaust pipe replacements, to name a few. Instead, Richmond performs battery maintenance and system inspections every few months. He looks for signs of heat, bad cables, and poor connections. He also cleans corrosion, tightens connections, and refills the water in the batteries.

Besides eliminating tailpipe emissions, Randy also uses renewable energy sources for recharging the EV's batteries—an 800-watt grid-tied PV system and grid power purchased from the Green Power program at Puget Sound Energy—eliminating the pollution associated with conventional coal or natural-gas-fired electricity production.

Though he misses A.M. radio reception, which is blocked by interference from the controller's PWM, Richmond couldn't be happier with the finished product. "I like driving by the gas station and never stopping," he says. "I like that I come home and plug in my car, just like plugging in my cell phone."

One major future expense will be batteries. In four to six years, Richmond will need to replace them or modify the electrical design to run on newer battery technology if it's available. Either scenario will cost $3,000 or more. But that's a small price to pay for a vehicle that could last more than 15 years and cut fuel costs by two-thirds, Richmond says.

Curing the Hiccups

As much as he enjoys his new ride, the vehicle is not without some shortcomings. It struggles to keep up with traffic on steep hills, forcing him to pull onto the shoulder for one hill along his regular commute to let other traffic go by. By opting for larger batteries instead of more batteries and higher voltage, Richmond chose to get more distance rather than have better acceleration. He'd expected to be able to push 1,000 amps to the motor (the full carrying capacity of the power controller), but he learned that flooded lead-acid batteries are limited to about 400 amps because anything higher could overheat and melt the battery terminals. Had he realized this limitation during the design phase, he could have used bigger cabling and added industrial grade terminals, which might have pushed the power limit to 500 or 600 amps.

The weight of the batteries only exacerbates the less-than-optimal acceleration situation. Richmond had wanted to keep the vehicle's weight under the gross vehicle weight rating (4,600 pounds), but the heavier, 260 AH batteries that he chose pushed the vehicle to 4,900 pounds and only

added a few extra miles to the driving range. In retrospect, he says he would have chosen smaller, lighter 225 AH (T-105) batteries. Reducing the amp-hours would have cost him a few miles of driving range but could have saved him about $1,000 and reduced the vehicle's weight by 300 pounds.

To improve the vehicle's performance, Richmond has made some minor changes. A tonneau cover over the bed not only improves the vehicle's aerodynamics but also prevents unauthorized access to the battery box, which comes with a latch but not a lock. New, low-rolling-resistance tires extend the driving range by a few miles and make manual steering a tad easier on the arms. A data-logging system, which plugs into the battery SOC meter on the dash, helps monitor the vehicle's efficiency. A tow bar, tow lights, and drive line coupling device will make towing easier—just in case he ever runs out of juice.

Despite the few glitches, Richmond enjoys every minute of the EV experience. From start to finish, research to test drive, the conversion took one year. "I've heard stories about people who converted vehicles in a weekend, but I'm a perfectionist. I took my time and learned a lot along the way," he says. "Sure, I made some mistakes, but I'm pleased with the end product and plan to drive it for many years to come."

Access

Kelly Davidson, *Home Power* Associate Editor, is living without wheels (that is, the motorized kind) in New Jersey. She daydreams of the day when bike lanes outnumber freeways and renewable energy powers a national mass transit system.

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EV System:

Café Electric • www.cafeelectric.com • Zilla motor controller

Canadian Electric Vehicles Ltd. • www.canev.com • S-10/Sonoma conversion kit

EV Source • www.evsource.com • Water-cooling system for controller

Manzanita Micro • www.manzanitamicro.com • Battery chargers

Trojan • www.trojan-battery.com • Batteries

Xantrex • www.xantrex.com • Link 10 battery monitor

Zivan • www.zivanusa.com • Battery charger

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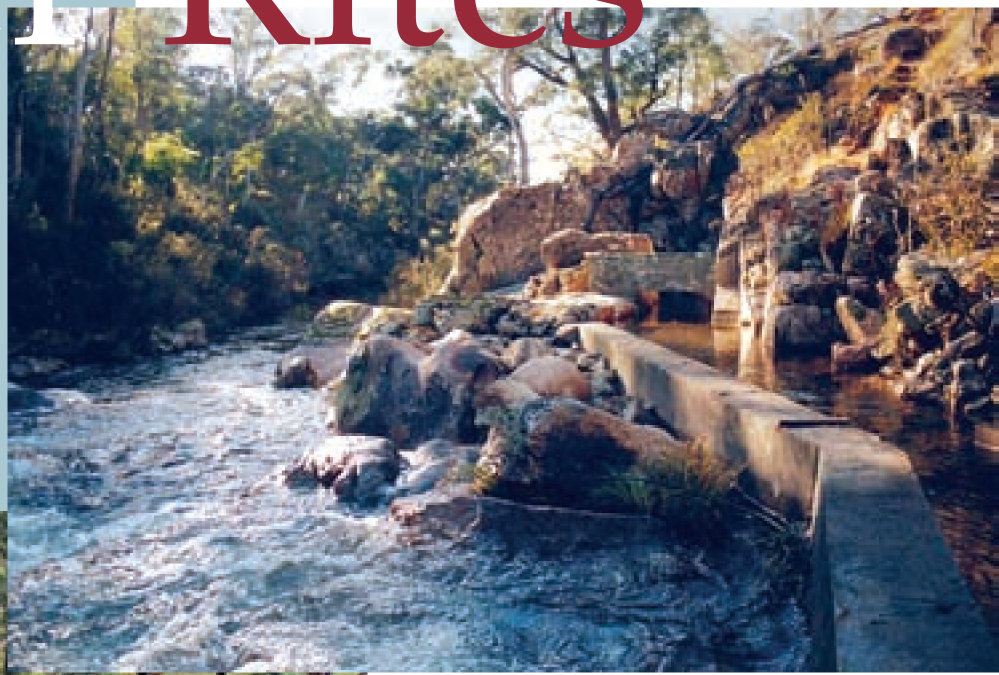


Above: The view downstream along the weir.
Left: The author with the new turbine.

Every morning, before brushing teeth or having a look at the weather outside our Victoria, Australia, off-grid home, my wife Carrie or I pad downstairs to the battery room to check the meters that monitor our electrical system. The reading determines whether we use the propane stove or the electric jug to heat water for our tea. Since our microhydro plant upgrade, it's usually the jug.

This ritual has become a part of our daily lives, like making the bed: A quick look at battery voltage and power from our microhydro system. It used to be a stomach-churning moment for us: Our previous microhydro turbine was dysfunctional too often due to its poor design, which meant a trip down to the river to clean the turbine blades—an uncomfortable and sometimes life-endangering task. Since replacing that "experiment" with an Energy Systems & Design (ES&D) LH1000 low-head turbine, complete with a prototype "leaf-mulcher," and new PV modules to back up the hydro, off-grid life's simply blissful.

Off-Grid with Comfort

Living in the most remote part of the Victorian Alps, 15 kilometers (9.3 mi.) from the electric grid, has not reduced my appreciation for flipping a switch rather than filling and lighting kerosene lanterns, using circular saws instead of hand saws, or for using other time-savers like toasters and microwave ovens.

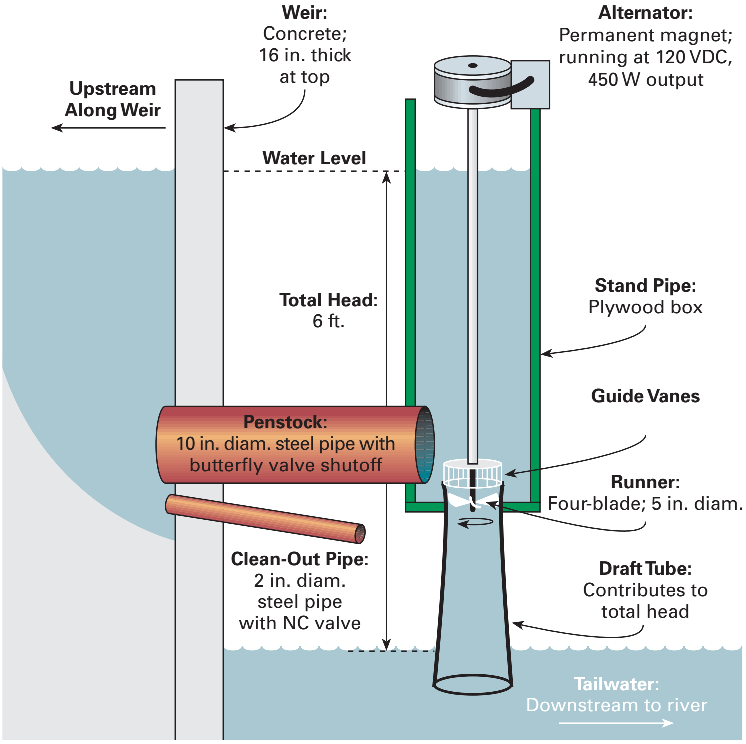
These days, although I'm an active 53 years old, I'm not content to spend my time chopping wood for cooking. Nor do I care to write by lantern light, or pull a coolish beer out of the river. Instead, I want plenty of free time to go trekking, kayaking, and skiing. Plus, I like my beer *ice cold*!

For the first few years, we had big problems with our original, locally engineered hydro plant (see "Choosing Microhydro…" in *HP101*). We feared that we'd made a huge mistake, as our time, money, and energy was sucked into the hydro like leaves. Friends and neighbors shook their heads at our folly. But our recent turbine upgrade has markedly reduced our "power plant management" needs, freeing several daily hours for ourselves, and now our off-grid life is good.

Microhydro Madness

It wasn't until after we installed our first contraption that we discovered it was a manufacturer's experiment in low-head axial turbines. Its many 90-degree angles impeded flow, making it inefficient. Its access port to the blades was too small for an average-sized adult, and usually under water, making debris clearing a freezing-cold, often dangerous nightmare. We kept a cardboard "turbine box" near the back door stocked with a dry suit, goggles, snorkel, life jacket, and safety rope. No kidding.

Hydro System Setup



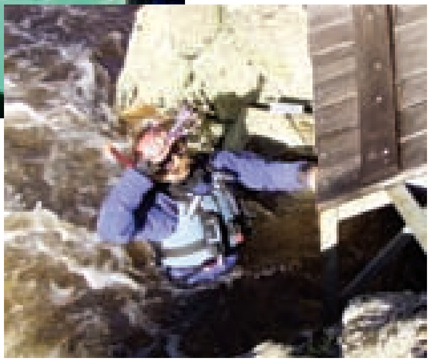
Microhydro turbine manufacturer Paul Cunningham measures the penstock.

The author works on attaching the penstock to the stand box.

Up and running—the first power output test.

The turbine's poorly designed blades often came loose and rotated to the wrong angle, either jamming the unit or causing the turbine to lose a lot of power. The complete turbine weighed in excess of 200 kilograms (441 lbs.), making its removal a time-consuming process that required a winch.

Another unfortunate problem was that we weren't informed to build the intake with debris screening in mind. All hydro plants have to contend with leaves, sticks, and other detritus. Because of the turbine and intake's design, we had to fiddle and mess with the turbine often, sometimes as much as three times a day. In contrast, a well-designed turbine intake should require a screen- or blade-cleaning perhaps once a week or, during summer low flows, once every few weeks. Unfortunately, when



Above: The new and improved clean-out procedure.

Right: The old, cold clean-out procedure.

Far right: A close-up of the custom leaf mulcher.

Hydro & PV Tech Specs

Overview

System type: Off-grid, battery-based microhydro-electric with PV

System location: Victoria, Australia

Site head: 1.8 m (6 ft.)

Hydro resource: 125 liters/second (30 gal./second), dry season; 190 liters/second (50 gal./second), wet season

Hydro production: 252 KWH per month ave., dry season; 291 KWH per month ave., wet season

Solar resource: 4.7 ave. daily peak sun-hours

PV system production: 45 KWH per month ave.

Hydro Turbine

Turbine: Energy Systems & Design LH1000, low-head propeller

Runner diameter: 5 in.

Alternator: Brushless permanent magnet

Rated peak power output: 1 KW

Hydro Balance of System

Hydro turbine controller: AERL Maximizer

Dump load: Two 400 W heat coils (resistors)

Inverter: Solar Energy Australia 2500, 24 VDC nominal input, 220 VAC, 50 Hz sine wave output

Circuit protection: 30 A breaker

System performance metering: Plasmatronics PL20

Photovoltaics

Modules: Sharp, ND-L3EJE, 123 W STC, 17.2 Vmp, 12 VDC nominal

Array: Two, two-module series strings, 492 W STC total, 34.4 Vmp, 24 VDC nominal

Array disconnect: 40 A breaker

Array installation: Homemade steel mount installed on north-facing roof, 48-degree tilt

PV Balance of System

Charge controller: Plasmatronics PL40, 40 A, PWM, 12–48 VDC nominal input and output voltage

Inverter: Solar Energy Australia 2500, 2.5 KW, 24 VDC nominal input, 240 VAC, 50 Hz output

System performance metering: Plasmatronics PL20

Energy Storage

Batteries: Lucent 1AVR 2/85-75L, 2 V nominal, 1,200 AH, sealed, valve-regulated lead acid (used telephone co. batteries)

Battery bank: One, 12-battery string, 24 VDC nominal, 1,200 AH total

we first built the weir, we did not understand the importance of a debris-screening strategy. Proper design greatly minimizes, or can even eliminate, manual debris removal. Including screening in the original design would have been easy, but now such an addition would be more difficult.

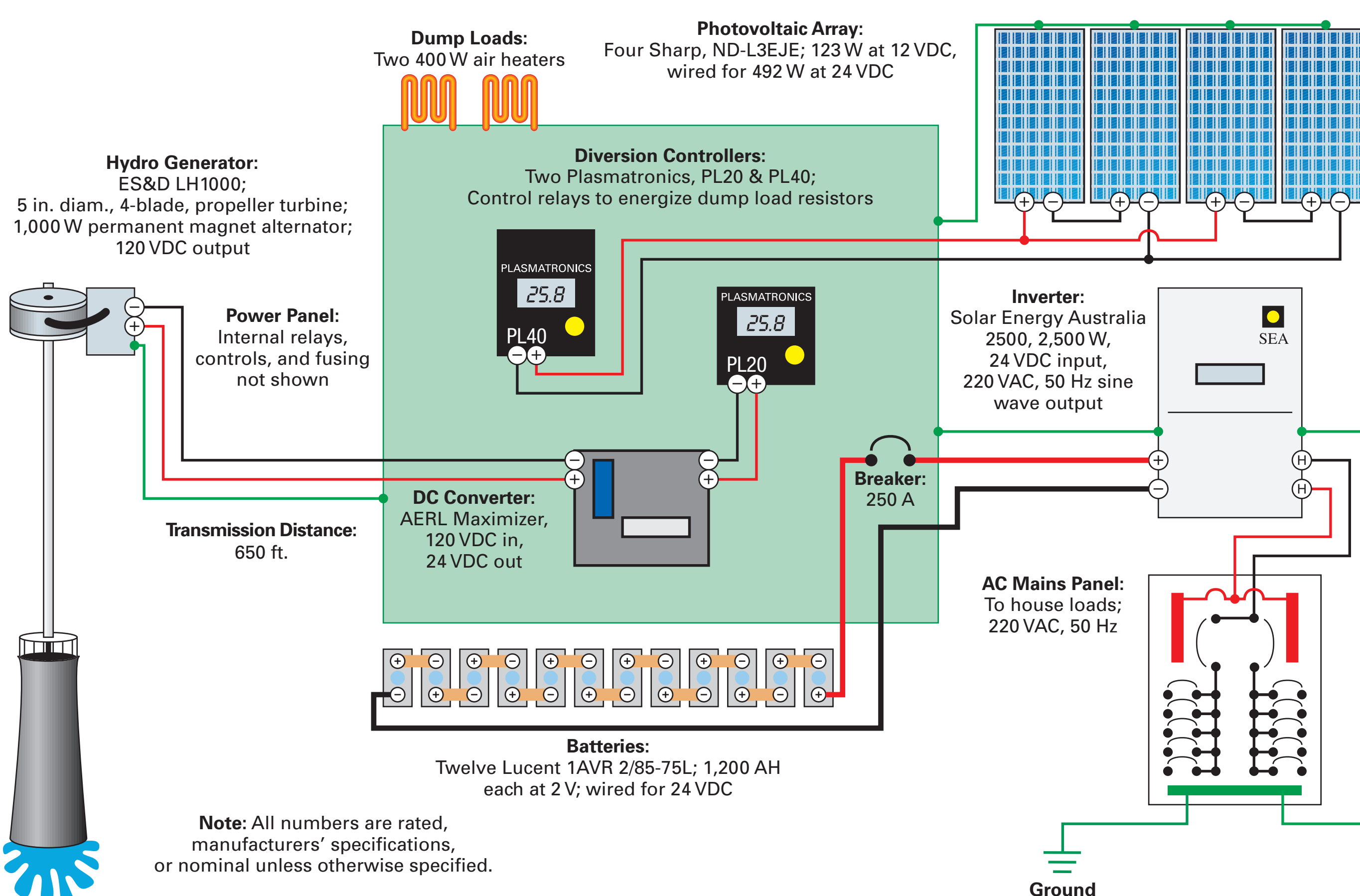
Our original turbine's 350-watt maximum output usually lasted only an hour or so after debris was cleared. After that, frequent checks of our Plasmatronics PL20 display would show the power declining steadily until we'd take our next forced march down the steep hill to reclean the turbine blades and intake screens. I dreaded the next flood or power drop, and dreamed of just going back to loving whatever mood the river was in. That cranky turbine cost us AU$6,000—three times more than the new ES&D LH1000 we replaced it with. Our naïveté and rush to build the hydro system cost us dearly—in money, time, and energy. On the plus side, we learned heaps about microhydro systems and renewable energy, and had in place all the other balance of system equipment—wiring, batteries, inverter, and regulator—for a new turbine. But we'd finally had enough—after five years of struggle, our patience and nerves were at an end, so we decided to replace the flawed turbine.

Through a microhydro e-mail list-server group (see Access), we received advice from several folks. Paul Cunningham, of ES&D in Canada, read my *Home Power* article from 2004, and felt that one of his turbines would work for us. The LH1000 turbine he recommended was a fraction of the size of our original turbine, weighing about 20 kilograms (44 lbs.). It has a strong, cast bronze runner/propeller, and could be made to offer blissfully easy access for unclogging.

The power wall.

We decided to give it a try and ordered one. Though Paul offered excellent support and advice over the phone and Internet, we invited him to visit us in Australia and help with the installation, and he accepted.

Aronson Hydro & PV System



Here, the stand box is coated with silt from a flood, but the turbine itself is easily removed if the river is approaching flood stage.

New Nuts & Bolts

With water flows of at least 125 liters per second (1,981 gpm), even during extended drought, and an average 1.8-meter (5.9 ft.) head, the new turbine was projected to provide at least 450 watts. Compared to the old machine, the new turbine required about 50 liters per second (800 gpm), so there was enough water to install two of the ES&D machines if need be.

It took half a day to remove the old turbine, and six people and a truck winch to drag the behemoth up the hill, where it remains lying in the long grass like a carcass. I've since sold its generator—a washing machine motor—for a couple hundred bucks, assuaging my need to recoup at least something from the beast.

It took just another day and a half to nut things out at the river with Paul. We built the plywood box that channels the water to the turbine and carried it down to the river, where we bolted it to the intake pipe. After making some adjustments, we slipped in the draft tube, clamped the new turbine to it, and opened the butterfly valve at the inlet. Just like that, we were up and running, and everything worked great on the first try! What a relief!

Sticks & Stones

We let our new turbine run for the first summer as-is, experimenting and observing. It worked well, regularly putting out about 450 watts. The debris problem remained, but was greatly diminished. With the old turbine, sticks, stones, and leaves worked their way to the blades. These would either clog the blades, or a stone or stick might even break one. Removing the clog meant the water torture of shutting down the turbine, opening the intake, which was often below water level, reaching and contorting to get an arm down to the blades, and grabbing out the glop bit by bit—all the while kneeling chest-deep in freezing water. Not fun.

But the ES&D turbine needs only minor cleaning. The new and improved muck-out process simply involved shutting the intake butterfly valve, removing one wall of the box, and sticking a finger or two through the vanes to wipe the tiny leaves and algae off the blades—all at eye level, high and dry above the water line. The shape of the inlet vanes prevents sticks from reaching the blades. Although stones can still get drawn into the box, they drop safely to the bottom, awaiting removal the next time the access port is opened. The concern became small leaves and algae, which drape themselves over the blades, slowing the turbine and reducing power.

Through the microhydro list server, I communicated with Michael Lawley of Eco Innovation in New Zealand. He'd been having similar debris problems with his Vietnamese-made, low-head unit, which he'd solved by inventing a simple "leaf-mulcher." Paul and I decided to adapt this great idea to our turbine.

The mulcher is a little piece of plastic with its end shaped to mirror the blade tops. It extends down below the inlet vanes about 1 millimeter (0.04 in.). Centrifugal force keeps the leaves at the outside edge of the blades, so the mulcher does not need to stick out very far. As the four blades spin, each passes by the mulcher 1,500 times a minute, which knocks or slices off the buildup. We had the mulcher in place all last summer and never once had to clean the blades! Plus, instead of reducing the turbine's power, its output actually increased!

Now, our cue to clean the new turbine kicks into gear when the meter shows the turbine output dropping to between 10 and 11 amps (from 13 to 15 amps normally), which, in summer or winter, can occur after several weeks, or, in autumn, after several days, instead of just a few hours. One of us strolls down to the falls and turns off the intake butterfly valve to drain the chamber. Then the valve is reopened a crack to direct a high-powered water jet onto one side of the inlet vanes, which washes the leaves and algae from the blades. Once that's finished, we open the valve fully to fill the box and restart the turbine.

RE Reliability

With a few lights and the stereo going, our household loads vary between 100 and 150 watts, depending on whether the fridge and/or freezer are running. If we use the microwave, toaster, or electric tea jug, the load can briefly increase to 1,200 watts. With our microhydro system, these loads are no problem at all, and, within a few minutes, we're back to dumping the excess energy from the hydro plant. Unlike off-grid homes that rely solely on small PV systems, where "phantom" loads from TVs, stereos, computers, and microwave clocks must be scrutinized, our hydro's continuous output means that we can just ignore them.

We recently added 492 watts of rooftop PV modules to our off-grid system. It's a cleaner, quieter backup to the microhydro system than an engine generator and has turned out to be a wonderful complement. During instances of flooding or, more rarely, when the turbine has to be shut down for maintenance, we still have enough energy to run most of our common household loads.

When the sun shines fully, the modules produce up to 450 watts. At the same time, the hydro is producing as much

as 450 watts. When everything's humming, the systems produce as much as 13 kilowatt-hours (KWH) daily! This is much more energy than we normally need, but having the two separate energy sources means that when the river is flooding or we're doing maintenance on the hydro, or conversely when the sun's been behind clouds for weeks, we still have plenty of energy.

With solar-made electricity, when the batteries are full, a charge controller cuts back the energy from the modules. But with microhydro, energy production does not stop—as long as water is flowing through the turbine. Switching off the electricity between the turbine and the battery will cause the turbine voltage to go too high. This scenario can create big problems, so those electrons have to go somewhere. When our batteries are full, a diversion controller shunts the excess hydro power to an air-heating resistance "dump load," dispersing it as waste heat, and keeps the turbine electrically loaded and running at the proper rpm.

Have a Cold One

We are quite pleased with the way the systems are working. No longer slaves to our turbine, we can leave for days without worrying about food in the freezer thawing. During floods or long bouts of clouds and rain, we don't have to hassle with a backup generator. Even in rare instances when the river is in flood and there are also several days of heavy cloud cover, we employ energy-conscious practices to make the energy stored in our battery last for two or three days.

There are still some projects ahead. We'll install a more permanent, metal turbine box, with a discreet cover to protect the turbine from flood debris and to hide the equipment from hikers, anglers, and our view. We'll be using some of our newfound time to plan a better pre-screening system to prevent debris or fish from working their way to the turbine box. Finally, we have a water heater coil awaiting installation in a hot water tank, so the excess energy our system makes can be put to good use. After these upgrades, we'll take a long break and have that ice-cold beer, compliments of our fully functional RE system!

Access

Jeffe Aronson (jeffe@tpg.com.au) is a 33-year veteran river guide, having rowed and paddled in South America, Australia, Africa, and the United States. He's owned a natural foods store, pioneered river trips in the Grand Canyon for disabled persons, and directed the historic restoration of downtown Flagstaff, Arizona.

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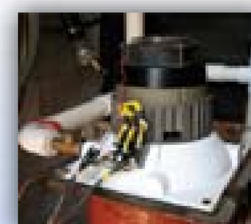


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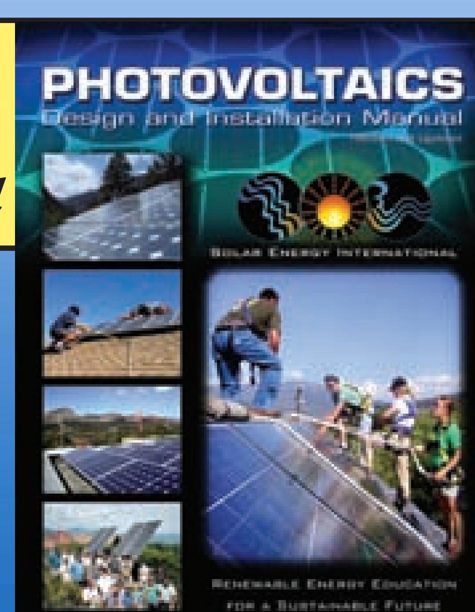

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Big Problems

Adapted from *Big Coal* by Jeff Goodell

John Blair/www.valleywatch.net

Every year, this coal-fired power plant in Rockport, Indiana, releases several million tons of carbon dioxide, a potent greenhouse gas; thousands of tons of sulfur dioxide, a chemical contributor to acid rain; and 1,300 pounds of mercury, a powerful poison, into the environment.

Until I was forty years old, I had never seen a lump of coal. Growing up in California, I'd visited hydro-electric dams in the Sierra Nevada foothills and wind farms east of San Francisco Bay. These sights made generating electricity seem easy and natural, like growing wheat or getting a suntan. It gave me the idea—one that I clung to for years—that it didn't really matter if I left the light on in the other room, because it just meant the hydro turbines and the wind generators had to spin a little longer.

I lost my innocence in the summer of 2001, when the *New York Times Magazine* sent me to West Virginia to write about the surprising comeback of coal during the early days of the Bush administration. Over the next few weeks, I visited several coal mines and talked with the engineers who worked in them. I drove to Cabin Creek, a narrow valley south of Charleston, West Virginia, where, in 1913, mining company thugs opened fire with Gatling guns on their own workers. I flew in a small plane over the southern coalfields, getting a bird's-eye view of the devastation wrought by mountaintop removal mining. I visited filled-in creeks and drove around with a local politician who explained to me with a straight face that flattening West Virginia was actually a good thing, because the state needed more level ground for golf courses.

The United States is more dependent on coal today than ever before. The average American consumes about 20 pounds of coal a day.

But the most memorable moment of that trip was a dinner I had with Bill Raney, the head of the powerful West Virginia Coal Association. It was less than a year after the 2000 election, and Raney's Beltway credentials were at an all-time high after his having helped deliver the state of West Virginia—and the Oval Office—to George W. Bush.

But it wasn't Raney's political connections that impressed me. Nor was it his defense of mountaintop removal mining as a necessary evil if West Virginia is to compete with coal mines in other states. It was what he said about technology. "The thing that people don't realize," Raney drawled, "is that if it weren't for coal, there would be no Internet, no Microsoft, no

Courtesy Vivian Stockman, www.ohvec.org, flyover courtesy southwings.org

The Kayford Mountain mine near Charleston, West Virginia, covers a 12,000-acre swath of once-forested, mountainous land. This is one of 450 mountains in the central Appalachian region that has been decimated by the mountaintop removal mining process.

Yahoo!" He leaned over his dinner plate. "Did you know that it takes more electricity to charge up a Palm than it does to run an ordinary refrigerator? And that every time you order a book from Amazon, you burn over three pounds of coal?"

I didn't know that. Later, I would find out that his calculations were wildly exaggerated. But his larger point about the interconnectedness of the dirty life of the mines and the sparkly pixels on my computer screen was correct. What Raney was really saying to me, I understood later, was this: You use a computer. You have lights in your house. You watch TV. You buy products manufactured using coal-fired electricity from stores that use the same. You are implicated in all of this. We all are.

Although America is a vastly richer country with many more options available to us, our per capita consumption of coal is three times higher than China's.

A Burning Issue

One of the "triumphs" of modern life is our ability to distance ourselves from the simple facts of our own existence. We love our hamburgers, but we've never seen the inside of a slaughterhouse. We're not sure if the asparagus that accompanies our salmon is grown in Ecuador or Oregon. We flush the toilet and don't want to know any more. If we feel bad, we take a pill. We don't even bury our own dead—they are carted away and buried or burned for us.

It's easy to forget what a luxury this is—until you visit a place like China. Despite its booming economy in recent years, the insulating walls of modern life have not yet been fully erected there. In restaurants, the entrees are often alive in a cage in the dining room. Toilets stink. When you flip the switch on the wall and the light goes on, you know exactly what it costs—all you have to do is take a deep breath and feel the burn of coal smoke in your lungs.

And coal is everywhere in twenty-first-century China. Plumes of coal smoke rise from rusty stacks on every urban horizon. There is soot on every windowsill and around

redmal/iStockPhoto

Excavation at an open cast coal mine.

the collar of every white shirt. It's what's fueling China's economic boom, and nobody makes any pretense that it isn't. But the toll of the rough journey China is undertaking is glaring. More than 6,000 workers a year are killed in China's coal mines. The World Health Organization estimates that in South Korea, 355,000 people a year die from the effects of urban outdoor air pollution, much of it resulting from burning coal. All over China, limestone buildings are dissolving in the acidic air. The first time I visited Jiamusi, a city in China's industrial north, it was so befouled by coal smoke I could hardly see across the street.

And it's not just the Chinese who are paying for their coal-fired prosperity. Pollution from China's power plants blows across the Pacific and is inhaled by sunbathers on Malibu beaches. Toxic mercury from Chinese coal finds its way into polar bears in the Arctic. Most seriously, the carbon dioxide (CO_2) released by China's mad burning of coal is helping to destabilize the climate of the entire planet.

All this would be much easier to condemn if the West had not done exactly the same thing during its headlong rush to become rich and prosperous. In fact, we're still doing it. Although America is a vastly richer country with many more options available to us, our per capita consumption of coal is *three times higher* than China's. You can argue that we manage it better—our mines are safer, our power plants are cleaner—but mostly we just hide it better. Most of us have no idea how central coal is to our everyday lives or what our relationship with this black rock really costs us. In addition, U.S. consumers buy many products from China, so we're in part responsible for the detrimental effects of China's coal industry, even if our use is one step removed. The pollution from China's coal-fired electricity crosses the same oceans as its exported products do.

Our Fossil Fuel Fix

In truth, the United States is more dependent on coal today than ever before. The average American consumes about 20 pounds of coal a day. We don't use it to warm our hearths anymore, but we burn it by wire whenever we flip on the light switch or charge up our laptops. More than 100 years after Thomas Edison connected the first lightbulb to a coal-fired generator, coal remains the bedrock of the electric power industry in America. About half the electricity we consume comes from coal—we burn more than a billion tons of the rock a year, usually in big, aging power plants that churn out amazing quantities of power, profit, and pollution.

In fact, electric power generation is one of the largest and most capital-intensive industries in the country, with revenues of more than $380 billion in 2005. And the rise of the Internet—a global network of electrons—has only increased the industry's power and influence. We may not like to admit it, but our shiny white iPod economy is propped up by dirty black rocks.

Energy-wise, a fundamental problem in the world today is that the Earth's reserves of fossil fuels are finite, but our appetite for them is not. The issue is not simply that there are more people in the world, consuming more fossil fuels, but that as economies grow and people in developing nations are lifted out of poverty, they buy cars and refrigerators, and develop an appetite for gas, oil, and coal. Between 1950 and 2000, as world population grew by roughly 140%, fossil fuel consumption increased by almost 400%. By 2030, the world's demand for energy is projected to more than double, with most of that energy coming from fossil fuels.

Between 1950 and 2000, as world population grew by roughly 140%, fossil fuel consumption increased by almost 400%.

We've been hooked on coal for almost 150 years now, and like a Bowery junkie, we keep telling ourselves that it's time to come clean, without ever actually doing it. We stopped burning coal in our homes in the 1930s, in locomotives in the 1940s, and by the 1950s it seemed that coal was on its way out for electricity generation too. Nuclear power was the great dream of the post-World War II era, but the near-meltdown of the Three Mile Island nuclear power plant in 1979 put an end to that. Then natural gas overtook coal as the fuel of choice. If coal was our industrial smack, natural gas was our methadone: it was cleaner, easy to transport, and nearly as cheap as coal. Virtually every power plant built in America between 1975 and 2002 was gas-fired. But natural gas production in the United States has been flat for several decades, leading us to import more and more from Canada, where production is also beginning to peak. There are still substantial reserves in places such as Russia and Qatar, but the global shipping and trading infrastructure remains undeveloped.

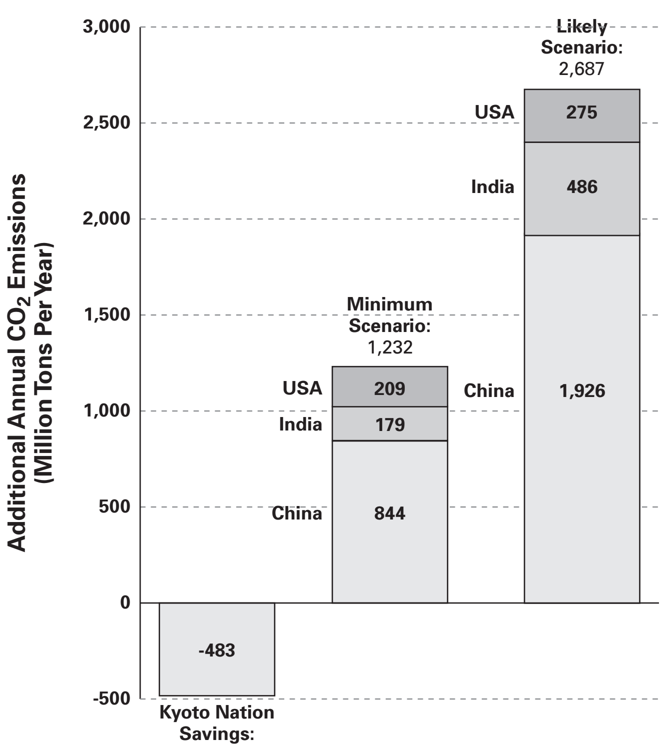
So coal has emerged as the default fuel for generating electricity. Coal has a number of virtues as a fuel: it can be shipped via boats and railroads, it's easy to store, and it's easy to burn. But coal's main advantage is that it's cheap and plentiful. There are an estimated 1 trillion tons of recoverable coal in the world, by far the largest reserve of fossil fuel left on the planet. In a world starved for energy, the importance of this simple fact cannot be underestimated: The world needs cheap power, and coal can provide it.

...by the time you mine the coal, haul it to the power plant, burn it, and then send the electricity out over the wires to the incandescent bulb still used in most homes, only about 3% of the energy contained in a ton of coal is transformed into light.

The Costs of Coal

Much of America is literally built upon thick seams of coal and has the geologic good luck of having more than 25% of the world's recoverable coal reserves—about 270 billion tons—buried within its borders. As coal industry executives never tire of pointing out, this is enough coal to fuel America at the current rate of consumption for about 250 years.

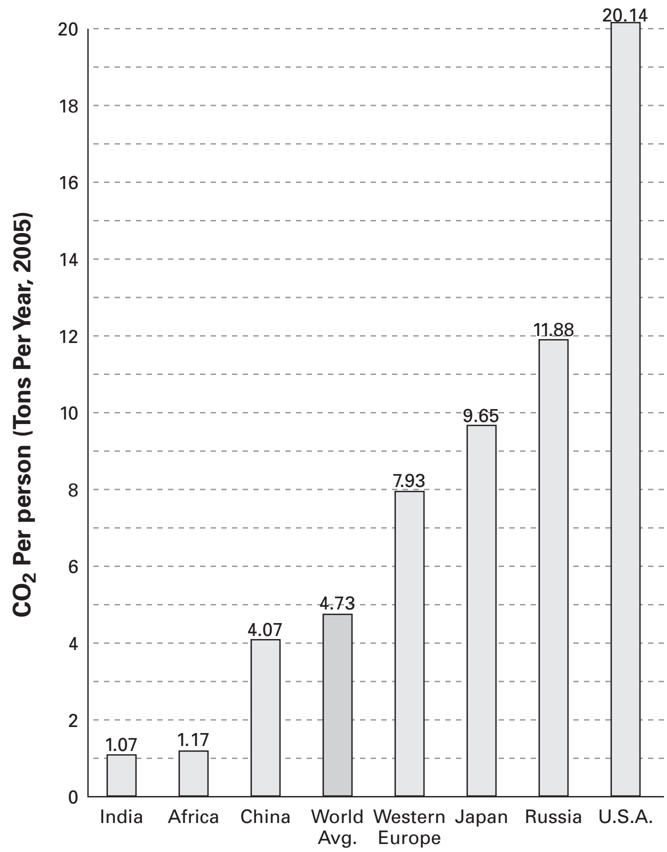
Projected CO_2 Emission Increases by 2012



By 2012, predicted cuts in greenhouse-gas emissions under the Kyoto treaty will be swamped by emissions from a surge of new coal-fired plants built in China, India, and the United States.

Sources: UDI-Platt's, U.S. Energy Information Administration, and industry estimates; Scott Wallace, *Christian Science Monitor* staff

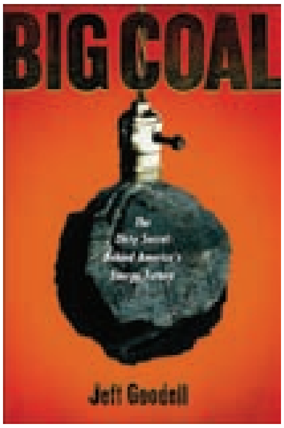
Average Annual Per Capita CO_2 Emissions from Fossil Fuels



Source: U.S. Department of Energy, Energy Information Administration, International Energy Outlook 2007

But this great bounty of coal is also a great liability. It means that America has a big incentive to drag out the inevitable transition to cleaner, more modern forms of energy generation. Renewable energy guru Amory Lovins estimates that by the time you mine the coal, haul it to the power plant, burn it, and then send the electricity out over the wires to the incandescent bulb still used in most homes, only about 3% of the energy contained in a ton of coal is transformed into light. In effect, America's vast reserve of coal is like a giant carbon anchor slowing down the nation's transition to new sources of energy. And because coal is the dirtiest and most carbon-intense of all fossil fuels—coal plants are responsible for nearly 40% of U.S. emissions of CO_2, the main greenhouse gas—a commitment to coal is tantamount to a whole host of environmental and public health issues, including global warming.

In America, the story of coal's emergence as the default fuel is inextricably tied up with corruption and politics. For Big Coal, this change in America's political and economic climate during the 2004 elections was transformative. As of 2006, more than 150 new plants, representing more than $130 billion in new investment, were either planned or under construction in the United States. Long-shuttered mines were



Big Coal **offers a behind-the-scenes look into America's addiction to shiny black rocks.**

reopening, and old coal miners were dusting off their boots. Wall Street analysts, in a swoon over the old rock, began cranking out pro-coal reports with titles such as "Come On Over to the Dark Side" and "Party On, King Coal!"

Lost in the hype, of course, is a sober accounting of what this new coal boom might really cost us. In 2006, 47 men died in coal mines, including twelve in an explosion at the Sago mine in northern West Virginia and two more after a fire in the Alma mine in the southern part of the state. In 2007, nine men died in Utah's Crandall Canyon mine. Since 1900, according to the U.S. Department of Labor, more than 100,000 people have been killed in coal mine accidents, many forever entombed by collapsed roofs and tumbling pillars. Black lung, a disease common among miners from inhaling coal dust, is conservatively estimated to have killed another 200,000 U.S. workers since the early 1900s.

Not so long ago, you could justify coal's dark side with a single word: jobs. ... Today there are more florists in the United States than there are coal miners.

And burning coal is even more deadly. In just the past 20 years, air pollution from coal plants has shortened the lives of more than half a million Americans. The broad legacy of environmental devastation—acid rain, polluted lakes and rivers, mined-out mountains—is impossible to tabulate. In Appalachia alone, the waste from mountaintop removal mining (instead of removing coal from the mountain, the mountain is removed from the coal) has buried more than 1,200 miles of streams, polluted the region's groundwater and rivers, and turned about 400,000 acres of some of the world's most biologically rich temperate forests into flat, barren wastelands. Plumes of toxic particles drift from Ohio northeast to Maine; a molecule of mercury emitted from the stack of a power plant in Tampa ends up in the brain of a child in Minneapolis. If and when fruit trees start growing on the Alaskan tundra, American coal burners past and present will be largely responsible.

Not so long ago, you could justify coal's dark side with a single word: jobs. In the 1920s, when more than 700,000 people worked in the mines, it was plausible to argue that miners were the backbone of the economy. Today there are more florists in the United States than there are coal miners. And if coal mining was the sure-fire ticket to wealth and prosperity that many in the industry claim, West Virginians would be dancing on gold-paved streets. Over the past 150 years or so, more than 13 billion tons of coal have been carted out of the Mountain State. What do West Virginians have to show for it? The lowest median household income in the nation, a literacy rate in the southern coalfields that's about the same as Kabul, Afghanistan, and a generation of young people who are abandoning their home state to seek their fortunes elsewhere.

The argument that cheap power is vital to keeping American manufacturers competitive is also suspect. At a time when U.S. auto manufacturers spend more money on health care for their workers than on steel for their cars, it's increasingly hard to make the case that cheap electricity is a major factor in keeping jobs from being exported to Asia. By contrast, a full-blown push for clean energy could unleash a jobs bonanza that would make what happened in Silicon Valley in the 1990s look like a bake sale.

...a full-blown push for clean energy could unleash a jobs bonanza that would make what happened in Silicon Valley in the 1990s look like a bake sale.

Coming Clean

During the three years I spent researching my book, about 3 billion tons of coal went up in smoke in America, creating light and heat for much of the nation. According to the American Lung Association, during those years, about 72,000 people in the United States died prematurely from the effects of coal-fired power plant pollution—more than from AIDS, murder, or drug overdose.

Obviously, there's no free power lunch: Nukes can melt down, dams flood valleys, and wind turbines kill birds. Building the modern world is fraught with trade-offs. But unlike in China or India, it's hard to argue that by burning coal to create electricity, America is lifting millions out of poverty and introducing them to hot showers and cold Cokes. Our affection for coal is essentially an old habit and an indulgence. At best, it's a short-term solution to a long-term problem. And the price of this indulgence may be higher than any economist can calculate.

Access

Jeff Goodell is the author of *Big Coal: The Dirty Secret Behind America's Energy Future* (Houghton Mifflin). He is a contributing editor at *Rolling Stone* and a frequent contributor to the *New York Times Magazine.*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FUELING a Revolution

by Claire Anderson
Photos by Sean Easly

Rolling up to the pump, you realize this isn't your father's Amoco station—or Chevron or Exxon, for that matter. What it is: One company's vision of choice and change for an industry that's been slow to facilitate either.

Drivers can fuel up with a variety of biofuels at the SeQuential station in Eugene, Oregon.

Two PV awnings, totaling 33 KW, serve a dual purpose, offsetting some of the site and store's electricity use and sheltering people at the pumps from the rain and sun.

The lush, "living" rooftop on the SeQuential Biofuel station is just one of the giveaways that this is no ordinary gas station. The labels on the fuel pumps are your confirmation. At this unique fueling stop in Eugene, Oregon, just off the heavily trafficked I-5 corridor, you can choose from a selection of domestically produced fuels—blends of biodiesel and ethanol for use in any diesel or gasoline engine.

Pathway to the Pump

This futuristic filling station has been abuzz with activity since its grand opening in September 2006, serving 400 to 700 customers a day who come to fuel up their cars with eco-fuel and their bodies with natural snacks from the store—

Below: Large windows on the storefront admit an abundance of natural light.

Organic coffee, with a smile.

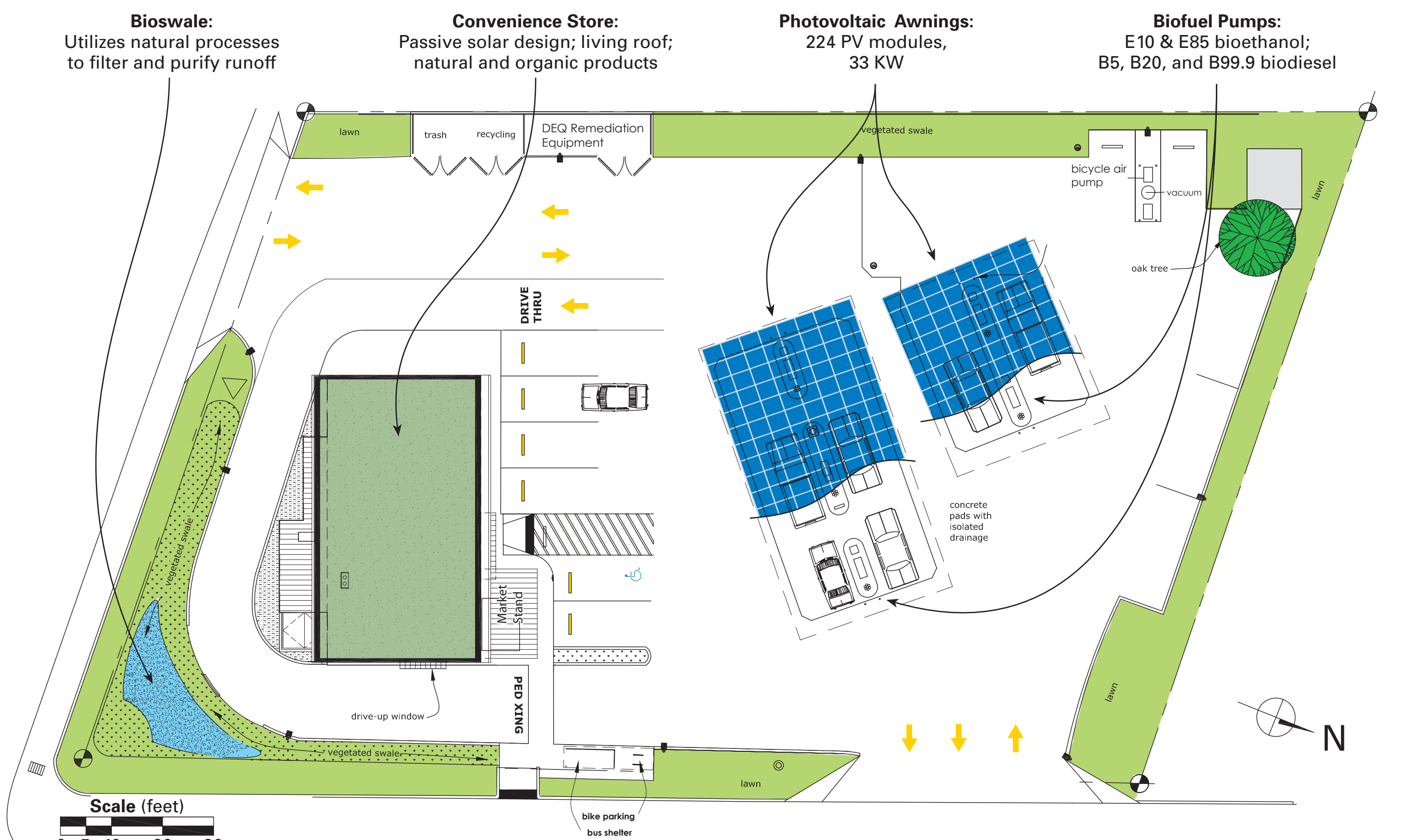
fair-trade coffee, natural sodas, and seasonal organic produce.

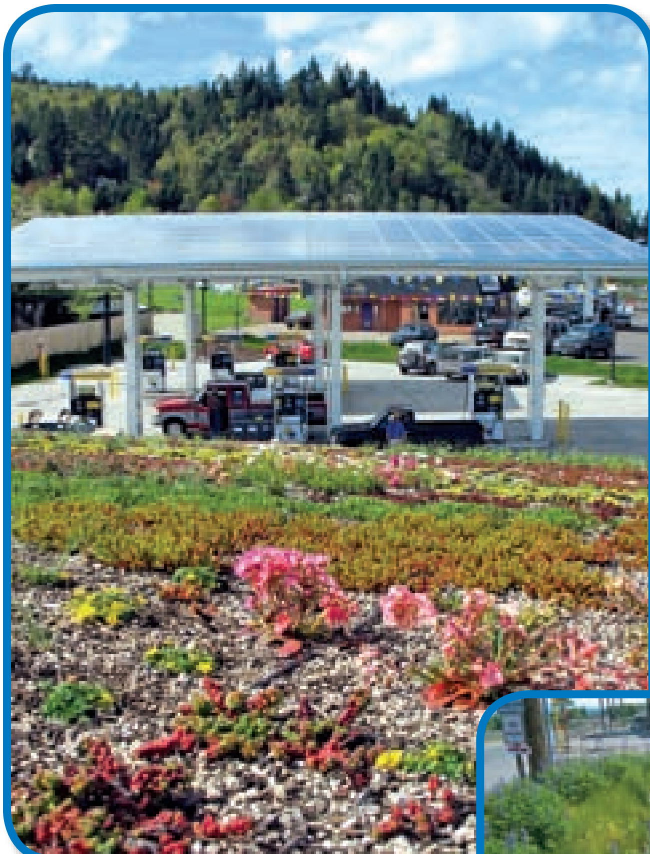
Although it's been somewhat of an overnight sensation, founders Ian Hill, Tyson Keever, and Tomas Endicott point out that the station was more than two years in the making. And their interest in renewable transportation has an even longer history.

A college independent study project sparked Ian's interest in clean energy and renewable fuels while he was working on a degree in environmental science at the University of Oregon in 1999. But it wasn't until he lost his pickup truck from "an incendiary demise during a road trip to California" that he started to more seriously consider renewably powered transportation.

"I upgraded my bicycle, and then spent the next six months researching electric cars, hydrogen fuel cells, car sharing, public transportation, and alternative fuels," says Ian. At the end of it all, he says, biodiesel appeared as the only option that met his criteria of being affordable and available.

SeQuential Biofuels Site Plan





Above: The store's living roof and PV array—both hard at work collecting sunshine.

A Smarter Rooftop

More than 4,000 plants rooted into the station's soil-covered rooftop help moderate the building's interior temperature. The layer of plants in 5 inches of soil acts as insulative mass, keeping the interior building space cooler during summer months. During west central Oregon's notoriously wet winters, the roof acts as a big biological sponge, drinking up rainwater before it hits the gutters and flows over the site as roof runoff.

These rooftop plantings work in concert with the overall site design. Because the station is located near the Willamette River, designers paid close attention to maintaining water and soil quality at and around the site. Bioswales are landscape elements filled with vegetation, compost, and riprap to capture pollution and silt from on-site surface runoff before it can make its way into the watershed. A variety of plants in the bioswales filter some toxic pollutants and sediments out of the water, and microorganisms in the soil further break down pollutants.

Left: Vegetated bioswales—constructed depressions in the landscape—intercept on-site runoff and capture pollutants.

In 2000, though, the only commercially available biodiesel in Oregon was prohibitively expensive, and had to be ordered and shipped in 5-gallon containers. So Ian took matters into his own hands, purchasing what many renewable-fuel enthusiasts consider the biodiesel bible—Josh Tickell's *From the Fryer to the Fuel Tank*—and investing the remainder of his insurance settlement from his truck-fire debacle into some home-scale biodiesel processing equipment and two identical 1982 Volkswagen diesel Vanagons. With some cooking oil collected from a local Italian bistro and other restaurant haunts, Ian and his longtime friend Tomas Endicott began brewing biodiesel in Ian's garage.

Word of Ian and Tomas's grassroots fuel-brewing adventures spread quickly throughout the small Eugene community, and they began to receive requests to present workshops at local events. Soon, Ian and Tomas, along with a handful of other friends, had formalized their homegrown interest into Eugene BioSource, and developed an informational Web site, traveled the local lecture circuit, and continued to make biodiesel for their own vehicles.

One year later, Tomas's brother Josh joined the group to help them investigate the viability of commercial biodiesel production. While Josh and Ian built a business case for a commercial biodiesel production facility in Oregon, commercial quantities of biodiesel manufactured from U.S.-grown soybeans became available in Portland. After striking a deal with another company to market blends of biodiesel, Ian, Tomas, and Josh became equal partners and registered their biodiesel distribution business in Oregon as SeQuential Biofuels LLC. "The capital 'Q' in the name is a symbol that represents 'source' or 'the sun,'" says Ian, "and the concept of 'sequential' connotes forward progress and change."

Their biodiesel business boomed, attracting government fleet contracts including the City of Eugene and Crater Lake National Park, and their wholesale market for B20 (20% biodiesel blended with petro diesel) quickly expanded beyond the Oregon borders. At the same time, SeQuential's requests for bulk deliveries of B100 were picking up—so much that, in 2003, they purchased an F250 diesel pickup and trailer, equipped with a 1,200-gallon tank and state-certified pump for on-road sales.

Tomas opened a SeQuential office in Portland, and soon SeQuential-branded B100 and B20 pumps were popping up all over the city. In Eugene, the original delivery truck continued to be the primary retail dispenser of B100, but business was beginning to pick up there too, and Ian seized the opportunity to grow the company and its sustainability goals.

Right: The SeQuential team.
Below: A driver marks his preferred fuel.

Ian says that he and Tomas had talked extensively about creating better options for "walking the talk," specifically taking responsibility for the impact that each individual's actions have on the environment, community, and economy. "Energy use has such huge ramifications where economics and the environment are concerned," says Ian. "We wanted to offer customers the choice to use environmentally friendlier fuels that create jobs and greater prosperity for both urban and rural communities in the Pacific Northwest."

Their vision? Create an experience that would draw the average person into the renewable energy movement, as well as offer renewable fuel products that work seamlessly with the existing fueling infrastructure and vehicles. The result: The first full-fledged service station in the United States to offer only bio-blended fuels.

Meeting the Sustainability Challenge

One of the biggest hurdles, Ian says, has been customer education. "About 97% of all passenger vehicles in the United States are gasoline-powered, and we've had to educate customers who drive gasoline vehicles that they can fuel up with E10 gasoline (10% ethanol) without harming their cars," says Ian.

"The irony is that many Portland-area drivers may be unaware that a small amount of biofuel is already blended into their fuel. For 15 years, the city's air quality standards have required that as much as 7.8% bioethanol be blended into all gasoline sold during the winter months." In 2006, the City of Portland passed a renewable fuels standard (RFS) that requires all gasoline in the city to contain at least 10% bioethanol and all diesel in the city to contain at least 5% biodiesel. The Oregon State Legislature passed a bill with similar provisions on July 3, 2007. Beginning February 1, 2008, all on-road gasoline in Oregon will contain 10% ethanol.

With the demand for biofuels increasing, Ian and Tomas say that another critical challenge for them is ensuring that this call is met with sustainable biofuels production. "Although biofuel production can be done in a positive, responsible way," says Ian, "it can also be done in a way that produces negative economic, social, and environmental impacts." He cites the trend to use imported palm oil from the tropics as a biodiesel feedstock as an example. Some countries are razing their rainforests and replacing them with palm oil plantations to meet the demand for fuel feedstock, leaving sustainability

Solar at the Station

Solar-electric modules mounted on the canopies above the pumps convert sunlight into clean electricity and are expected, annually, to generate almost 50% of the electricity required for the station's fuel pumps, lights, and appliances. Since the station's opening last September, the PV system has generated more than 40 megawatt-hours of electricity and offset almost 24 tons of carbon dioxide.

Besides providing renewable electricity for the station, the sun also serves the retail store, an unassuming 2,000-square-foot building that is anything but typical. Large windows on the storefront admit an abundance of natural light during the winter months. A centrally located thermal storage wall made of masonry minimizes interior temperature swings, and helps keep the interior comfortable while reducing reliance on mechanical heating and cooling systems. In the summer, simple passive cooling strategies, like awnings that shade the windows, keep the sun at bay and keep the store at a refreshing 70°F.

proponents to question whether biobased fuels are really a sustainable solution.

SeQuential's Salem-based biodiesel production facility, a joint venture with Pacific Biodiesel of Maui, Hawaii, predominately processes used cooking oil collected from restaurants and food processors throughout Oregon and Washington, and they are aiming to offer only Oregon-made biodiesel at the station in the next year. Although part of their bioethanol feedstock supply currently comes from the Midwest, they also source ethanol from the Pacific Ethanol facility in Boardman, Oregon, to support more regional supplies.

"Perhaps the greatest positive impact of biofuels produced in the United States from U.S.-grown crops is that the money spent to purchase and consume biofuels stays in the pockets of businesses and farmers here," says Ian.

Fueling the Future

Ironically, Ian points out that because the present scale of energy consumption in the United States is so massive, "no matter what 'alternative' fuel or energy sources we develop, energy insecurity and pricing volatility are going to be problems in the years ahead," and concedes that the most sustainable choice has less to do with fuel and more to do with vehicles.

"The most sustainable fuel is that gallon that's never used," says Ian. "Using less fuel by choosing vehicles with higher fuel efficiency is the most significant thing that we can do, and driving diesel passenger vehicles and gasoline hybrids that get 45 mpg or more could go a long way to improving the situation."

And yet he still harbors hope for the future of biobased fuels, and believes that SeQuential's approach, which introduces products that work with an existing infrastructure and fit within a more sustainable environmental and economic framework, will "also lead the country in the direction of SeQuential's long-term sustainable goals—fostering a strong domestic and regional economy and exceptional environmental quality."

Sound like lofty goals in the face of growing energy crisis? Maybe, but that's what fueling a revolution is all about.

Access

Claire Anderson (claire.anderson@homepower.com), *Home Power*'s managing editor, is still holding out for her dream wheels: a hybrid biodiesel-electric pickup. In the meantime, she relies on her trusty station wagon or veggie-oil-fueled F250 truck to make trips into town.

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Courtesy Loren Simpelo www.smugmug.com

GEAR FOR THE NEW YEAR

SOLAR POWER 2007 HARDWARE HIGHLIGHTS

by Ryan Mayfield & Joe Schwartz

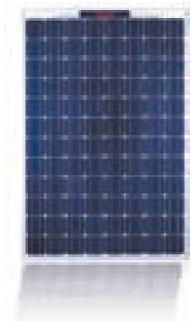
For solar energy gearheads like us, nothing beats a few days on the Solar Power Conference exhibit floor. Inside, manufacturers from around the world debut new PV and solar thermal products, and share visions of equipment that's on the horizon. The excitement surrounding the product innovations on display is palpable, and you can't help but get the sense that big things are underway in renewable energy equipment research and development.

The equipment on the following pages is just some of the hardware that caught our eye at the show. Some of the included products will decrease installation time, others offer fixes to current equipment limitations, and some interesting trends are mentioned as well. The hardware listed spans the residential and commercial RE markets.

Note that some of the showcased products are not currently in production or available in the United States, and some haven't yet been listed by Underwriters Laboratories or an equivalent certification agency. But all of the gear that follows is promising, cutting-edge technology, and while not all of the products covered will result in dramatic changes in RE system design or installation, there are sure to be more than a few success stories here.

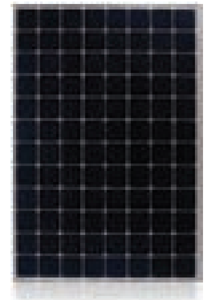
PHOTOVOLTAICS

Sanyo: HIT Double Series PV; www.us.sanyo.com
In 1997, Sanyo introduced their high-efficiency HIT PV technology that combines single-crystalline cells with thin layers of amorphous silicon. More recently, Sanyo released their HIT Double module line. The double-glass structure allows reflected sunlight, including that which passes through the module, to be captured, resulting in maximum output gains of approximately 30% in some installations. The Sanyo Double is an attractive product (aesthetically and in terms of energy production) for awnings, carports, and building facades.



Schuco: S PMU-2 Series PV; www.schuco-usa.com
Standing more than 7 feet tall, the 300- to 340-watt Schuco S PMU-2 Series is one of the highest-power modules manufactured, and just might be the best-looking PV we've seen. Schuco also manufactures similarly sized thermal collectors, and their complete building-integrated roofing systems have been in play in Europe. We're looking forward to their presence stateside. Schuco also unveiled a new flat-roof PV ballast mount that allows for module tilts between 7.5 and 30 degrees.

SunPower: SPR-315E PV; www.sunpowercorp.com
Going with the theme that bigger is better, SunPower's SPR-315E is a high-efficiency, high-power PV for commercial applications. The 315-watt module boasts an efficiency of 19.3% and a high-density power yield of 17.9 W per square foot. High-density power yield is an increasingly important design feature in many installations, and this module delivers. Reduced temperature coefficients compared to many other crystalline modules result in increased energy harvest in real-world environmental conditions.



Asian PVs: New module lines are destined for the United States.
One of the most noticeable trends was the dramatic increase in Asian PV manufacturers entering the U.S. market. Some of the new players include Lucky Power, NB Solar Systems, Solar Fun, Sunowe, and Trina. Some of these manufacturers have already established U.S. brands and distribution, while others are still in the process of obtaining UL listings and distributor relationships. Time will tell how much traction these companies will gain in the U.S. market and how their PVs will perform in the field.

Courtesy www.suntech-power.com

Building-Integrated PV (BIPV): Shingle and architectural-glass photovoltaics. BIPV products were a common sight at many of the PV manufacturers' booths. Solar "shingles" were on display by manufacturers such as BP, Open Energy, SunPower, and UniSolar. Lucky Power, Open Energy, and Schuco were displaying architectural-glass PV products for use in carports and vertical curtain walls. In addition, various colored PV cell options for BIPV applications were on display, offering new choices to match the aesthetics of PV arrays to building designs.

Courtesy www.schuco-usa.com

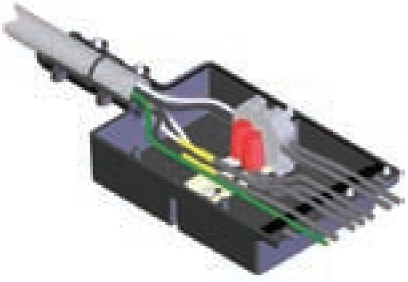
RACKING & CABLE MANAGEMENT

DP&W Power-Fab: Power Tube CRS ballast mount system; www.power-fab.com
DP&W's Power Tube CRS ballast mounting system is an innovative approach to PV mounting for flat-roof applications. Their design allows for PV tilts of either 5 or 10 degrees. The system's unique advantage is that the array weight accounts for the majority of the ballast requirements, reducing the number of masonry blocks required. The result is a ballasted PV installation with a total weight of less than 5 pounds per square foot.

Quick Mount PV: PV mount flashing; www.quickmountpv.com
Proper roof penetrations and waterproofing methods are of utmost importance to installers and homeowners. The Quick Mount PV flashing system is designed to enable fast installations with high-quality penetration sealing. The aluminum construction and included stainless steel hardware ensure component longevity. The flashing system is designed to work with composition, shake, and tile roofs. The integrated standoffs can be paired with most racking systems.

Sharp: Solar Rack System (SRS); www.sharpsolaritson.com
The new Solar Rack System from Sharp is one component of their OnEnergy PV systems. One of the racking system's most impressive features is that it integrates a UL-listed module-to-rail grounding system that eliminates running an exposed equipment grounding conductor from module to module, reducing installation costs. The racking system is part of a pre-designed, made-to-order kit that can be customized by the installer via Sharp's Web-based system design tool.

UniRac: Rapid Rac G10 ballast mount system; www.unirac.com
Designed to reduce module installation time and complexity, the Rapid Rac G10 is a modular approach to ballast racking, with a 10-degree tilt as the standard. Each rack has a ballast bay to house masonry blocks directly in front of and behind the PV modules. Another UniRac product, the Rapid Foot fastening system, can reduce the ballast requirements in high-wind locations, using minimal roof penetrations.



Wiley Electronics: Acme Conduit Entry; www.we-llc.com
Wiley Electronics introduced the Acme Conduit Entry (ACE) junction box that allows for a clean transition from PV USE-2 output conductors to THWN-2 home-run wiring. The NEMA 3R clamshell box is available in two sizes to allow for either four or six PV input strings. A unique conduit attachment approach allows for connection to EMT, RNC, or LFNC conduits. Wiley also introduced a stainless steel cable clip designed to secure two USE-2 conductors to module frames.

INVERTERS & CONTROLS

Fronius: IG Plus inverter line; www.fronius-usa.com
In response to installer feedback, Fronius has updated their already-popular IG series inverter line. The new IG Plus platform includes 4 KW, 8 KW, and 12 KW models. The IG Plus incorporates several new features, including field-selectable AC voltage, and a positive or negative grounding option. The series also includes a six-pole, fused combiner box and DC disconnect that can be conveniently decoupled from the inverter if servicing is required.

OutBack Power Systems: FLEXmax 80 Controller; www.outbackpower.com
A few years back, OutBack's MX60 controller fundamentally changed battery-based PV system design. Finally, PV arrays could be configured at high voltage (up to 150 Voc) and charge a variety of lower nominal battery voltages. OutBack will be introducing a new maximum power point tracking (MPPT) controller to their product line—the FLEXmax 80. The controller has an improved, continuous MPPT algorithm and an 80-amp output capacity with no thermal derating up to 104°F (40°C) ambient.

PV Powered: PVP30KW inverter; www.pvpowered.com
PV Powered displayed their new commercial line of 30 KW, 75 KW, and 100 KW inverters. The NEMA 3R enclosures have integrated load-break-rated AC and DC disconnects. The units are field-configurable for either 208 V or 480 V output. Additional integrated features include an automatic overnight disconnect that eliminates tare losses and a soft-start circuit to minimize nuisance faults. Their standard PVM1010 module provides Web-based monitoring of critical system parameters.

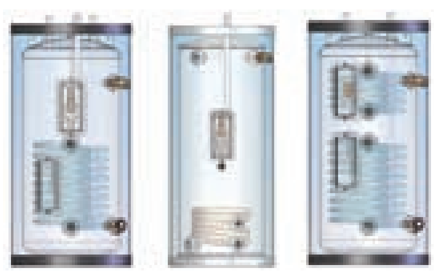
SMA America: Sunny Island 5048U; www.sma-america.com
In the United States, AC coupling (using a battery-based inverter to regulate the AC output of batteryless inverters) is still a relatively new idea. SMA's new Sunny Island (SI) 5048U battery-based inverter is designed for AC-coupled system integration, as well as traditional DC-coupled PV systems. New features include the ability to stack up to four inverters for 20 KW output and an improved user interface. The SI 5048U can be used in grid-tied battery backup applications, as well as remote off-grid systems.


Courtesy SMA Technologie AG

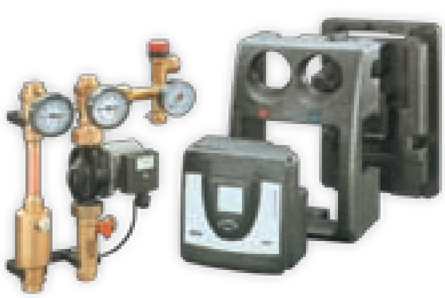
Xantrex: XW inverter and charge controller; www.xantrex.com
Xantrex announced that several additions to their product line are now shipping, including their XW inverters and charge controller. The XW inverter line offers split-phase 120/240 VAC output and supports two AC charging sources. Three models are available: 6 KW and 4.5 KW at 48 VDC, and 4 KW at 24 VDC. The XW-MPPT60-150 controller operates up to 140 VDC (150 Voc limit), has a 60-amp rating at 113°F (45°C) ambient, utilizes passive cooling, and includes integrated ground-fault protection.

SOLAR THERMAL & HYDRONIC

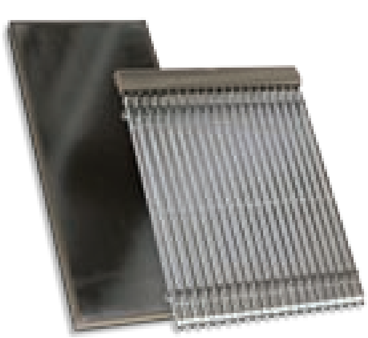
Caleffi: Solar thermal circulation stations and controls;
www.caleffi.us
Headquartered in Italy with worldwide distribution branches, Caleffi is bringing advanced European solar thermal and hydronic components to the United States. Their product line includes air vents, mixing and diverting valves, solar circulation stations, differential controllers, and system performance dataloggers. Caleffi's iSolar DL datalogger allows for Web-based system performance monitoring and thermal system control configuration when used with the iSolar Plus differential controller.



Heat Transfer Products: Solar thermal storage/exchange tanks;
www.htproducts.com
Established in 1974 and based in Massachusetts, Heat Transfer Products is a longtime manufacturer of high-efficiency boilers. HT Products also offers a complete line of solar thermal exchange tanks, both glass-lined and stainless steel. Depending on the model, tanks integrate one or two heat exchangers; electric, indirect boiler, and gas-fired backup options are available. Solar-ready models include the SuperStor Contender Solar, SuperStor Solar, and the Phoenix Solar.



Oventrop: Solar thermal circulation stations and controls;
www.oventrop-na.com
Oventrop's Connecticut-based distribution center is bringing German-engineered, integrated solar thermal systems to the U.S market. The OVSOL System 5 includes a 16-tube evacuated collector. The Regusol 130 circulation and control module is a completely integrated package that includes the circulator, system controller, valves, and gauges in a compact, pre-assembled, fully insulated unit. The complete system includes an 80-gallon stainless steel storage tank with two integrated heat-transfer coils—one for solar thermal input, and one for auxiliary heat from a backup boiler.



Viessmann: Solar thermal collectors, tanks, and controls;
www.viessmann-us.com
Viessmann manufactures both flat-plate (Vitosol 100) and evacuated tube (Vitosol 300) thermal collectors. We've never heard such straight-up, expert commentary on the appropriateness of one collector type versus the other for a given application. Viessmann was displaying some of the most highly engineered and installer-friendly complete solar thermal systems we've seen, right down to fittings that virtually eliminate all pipe solder connections during installation.

Access

Ryan Mayfield (ryan@mayfieldsolar.com) earned a degree in environmental engineering from Humboldt State University and now lives in Corvallis, Oregon. He has been working in the RE field since 1999 and founded Mayfield Solar Design, focusing on PV system design, implementation, and industry-related training. He holds a Renewable Energy Technician license in Oregon.

Joe Schwartz (joe.schwartz@homepower.com), *Home Power* CEO and executive editor, has his snowplow (and his telemark skis) tuned and ready for the big winter ahead. Joe holds a Renewable Energy Technician license in Oregon, and his off-grid home and home office are powered exclusively by renewable energy.

Solar Power 2008 will be held October 13-16, 2008, in San Diego • www.solarpowerconference.com

green FROM THE GROUND UP

by Jim McKnight, Mark Klein & Laura Lee

Guy and Maria Janssen own a popular coffee shop in Stevens Point, Wisconsin, named Emy J's after their 12-year-old daughter. The business shows off their environmental values—like serving fair-trade organic coffee, using a high-efficiency coffee roaster, using biodegradable cups and plates, and purchasing renewable utility power and carbon offsets.

In 2005, they invested in a solar hot water (SHW) system for their coffee shop and other building tenants. "We do these things because we believe that in doing so we give back to the community, the environment, and to the world at large," says Guy. From that philosophy, and with the positive solar experience fresh in their minds, the Janssens contacted our sustainable building company, Gimme Shelter Construction, to incorporate renewable energy (RE) and sustainable building techniques into the new home they were planning.

The building site, which sits west of town on a bank above the Wisconsin River, is populated with oaks, maples, and pines that are reclaiming the farm fields of Wisconsin's early pioneers. We identified a south-facing rise which provided an open, unshaded site—perfect for a passive solar home and the planned SHW and solar-electric systems.

Solar Tenets for Solar Tenants

The 2,600-square-foot Janssen home is based on the tenets of passive solar design, including proper building orientation, optimum window placement, natural daylighting, and thermal mass within an efficient building envelope.

The longest wall of the home was oriented to 2 degrees east of true south to optimize solar gain. The majority of windows, equal to 9% of the total floor area, were placed along this wall. Windows facing east and west make up 4% of the floor area, while there are only two small windows on the north side of the building to minimize heat loss. The window layout added good household cross-ventilation, and natural daylight for every room.

Thermal mass in the interior—a 2.5-inch-thick concrete slab on the first floor, plaster finishes on the walls, and a 5-ton masonry heater—helps store solar gain in the winter and moderates temperature swings during the cooling season.

Maria, Emy, and Guy Janssen pose on the locally quarried sandstone steps leading up to their house.

ECO-EFFICIENT BUILDING STRATEGIES

Passive solar design—Reduces heating and cooling loads by 10% to 15% through proper solar orientation, window placement, and interior mass.

High-performance building envelope—Reduces heating loads an additional 40% to 50% through higher insulation values, high-efficiency windows, using a continuous vapor barrier, and sealing penetrations.

Masonry heater for space heating—Uses local biomass as fuel.

PV system and solar thermal system—Use a free, renewable energy source (sunshine) to provide electricity for the house and space and water heating. Can be sized smaller as a result of efficient building design and construction. Heater and solar hydronic systems are locally made, reducing their embodied energy.

Heat recovery ventilation system—Brings in fresh air to the home and controls indoor humidity while minimizing heat lost to indoor/outdoor air exchanges.

Interior choices: cabinets, subfloors, paints, and finishes—Formaldehyde-free sheathing, and low-VOC paints and finishes don't compromise indoor air quality.

Sustainably harvested wood—Supports local milling operations and foresters, and healthier ecosystems.

Acid-etched concrete—High embodied energy of concrete is offset by its durability and low maintenance requirements, plus its improvement of the home's thermal performance.

Steel roof—More durable and better value than asphalt shingles; recyclable at end of life span.

We used a continuous vapor barrier with careful sealing, spray-on cellulose insulation (R-32 in the walls; R-60 in the ceiling), dropped sidewall framing (where the wall insulation extends below the floor level), and triple-pane windows. Combining a superinsulated shell with passive solar design reduced the heating and cooling needs to about 40% of a standard Wisconsin Energy Star-rated home. But having such a tight building envelope necessitates bringing in fresh air during the heating season, so a heat recovery ventilator was included (see Fresh Air sidebar).

For the Janssen home, the combination of having a high-efficiency building envelope and passive and active solar technologies will result in utility bills for the heating season being about 60% less than a typical home of the same size, and reduce carbon dioxide (CO_2) emissions by nearly 7 tons annually. The Janssens, who are also committed to using the sun to provide electricity, hot water, and space heating for their home, the carbon reduction is even greater—nearly 12 tons per year.

Left: Laying the masonry heater's refractory brick. Right: The final product in action!

Warming Systems

A 320-square-foot closed-loop glycol solar hot water system provides domestic hot water and primary space heating through hydronic tubes in the concrete floors, producing about 35 million Btu per year. A 50-watt PV module powers a DC pump, which circulates the glycol mixture through ground-mounted collectors in the garden, through insulated, buried lines, then to the storage tank. This system provides enough hot water for in-floor space heating for early spring and late fall, plus plenty of domestic hot water year-round. During the peak heating season in December and January, supplemental heat is needed.

A high-mass (masonry) wood heater provides extra space heating and supplemental water heating during the colder months. There is plenty of fuel from small woodlots in the area, so masonry heaters are becoming more common. They are one of the most efficient ways to heat with wood, and homeowners love the comfortable, radiant heat.

Guy and Maria prioritized integrating hot water capability into the masonry heater to assist the solar collector. A stainless steel exchanger within the secondary combustion chamber heats water that's routed to the storage tank in the basement. This stored heat is used both for domestic hot water and space heating.

Because they are designed for relatively quick burns at temperatures above 1,800°F, masonry heaters are convenient and efficient. Superheated flue gas circulates through a series of chambers and most of the heat is absorbed by the 5-ton mass of the heater before exiting the chimney. Masonry heaters are about 70% efficient, roughly equal to EPA-qualified wood heaters. The high combustion temperature produces very low emissions—about 2 grams of particulates per hour (typical wood heaters produce about 15 grams per hour; outdoor wood-burning boilers can produce about 40 grams). Because masonry heaters burn so cleanly, flues and chimneys need

FRESH AIR

A heat recovery ventilator (HRV) helps maintain good indoor air quality by exhausting stale inside air while drawing in fresh outside air. HRVs help control relative humidity, preventing moisture buildup on windows and reducing the chances of mold (a HEPA filter can be added to remove dust and pollens). As the two airstreams—indoor and outdoor—pass through a heat-exchanging core, most of the inside air's heat is transferred to the incoming air. Even at an outdoor air temperature of 32°F, the Janssens' Bryant HRV can exchange 211 cubic feet per minute with 69% to 77% percent of the heat transferred back to the incoming air.

Typically, inside air to the exchanger is pulled out of high-moisture areas like baths and kitchens, while fresh air is supplied to bedrooms, assuring whole-house circulation. Although most HRVs are programmed to run intermittently at low speed, a high-speed override can provide on-demand venting when moisture levels are high.

A straightforward installation costs about $3,000, but the recovery of 70% or more of the heat otherwise lost through an exhaust-only system can offer significant savings, especially when extreme differences exist between indoor and outdoor temperatures.

Alternatives to HRVs include exhaust-only ventilation systems, which use standard exhaust fans and a dampered makeup air supply. They are less expensive and consume less energy, but require the homeowner to monitor conditions and adjust the system's timer accordingly. They also will not maintain a preset humidity and will not recover the heat lost when venting directly to the outside.

The concrete tank in the basement used for hot water storage.

Right: Heat exchanger coils inside the tank.

Below: The systems' mechanics wall, with the expansion tank, circulators, and boiler next to the PV system inverter and other electrical equipment.

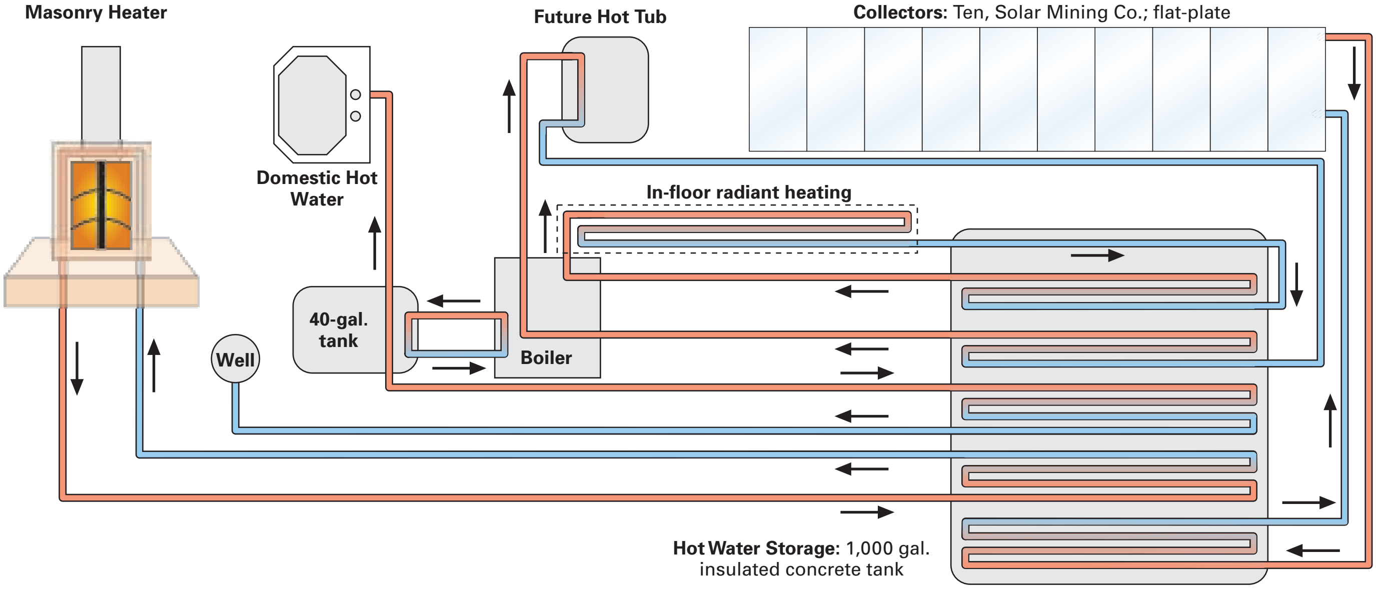
less frequent cleaning than for typical wood heaters, usually once every five years. Masonry heaters are about 70% efficient, roughly equal to EPA-qualified wood heaters.

The heat-transfer efficiency and heat-storage capacity of the large mass keeps combustion time relatively short—three to four hours per day in midwinter—which translates into much less interaction required by the owner and a flexible firing schedule. When the days warm, firings can be spaced out even further because the rate at which heat radiates slows as room temperature rises. This phenomenon is true of all radiant heating systems, including in-floor hydronic systems.

A masonry heater is built with a core of cast refractory parts and firebrick, surrounded by a veneer of stone, brick, or block. The Janssens' heater has a solid 4-inch block veneer with a troweled plaster finish. The heated bench and the mantel are slabs of local sandstone.

Ideally, heaters should occupy a central location on the main living floor to take advantage of the radiant surfaces on all four sides. The heater can bear ceiling and roof loads, so designing homes with a central heater can open up areas that would have been obstructed by posts or bearing walls. Radiant heaters help prevent temperature stratification common with forced-air heating systems. We've had success heating two-story homes up to 3,500 square feet with a single masonry heater. Although they can be expensive—the Janssens' heater cost about $20,000—the benefits of a hearth experience and supplying heat with a renewable, local resource make the choice easier. Standard wood heaters are much cheaper, but they can't supply the quality of heat, ease of operation, decreased use of firewood, and longevity of a masonry heater.

Janssen Hot Water Plumbing



Left: The hydronically heated first floor, before and after the thin-slab concrete was poured.
Right: The finished floor and the earth-clay plastered walls help create an elegant, but earthy, atmosphere.

For backup when the wood heater is not being fired or when weather prevents solar heating, a Trinity 150 on-demand propane boiler helps out. The boiler monitors the incoming water temperature from the storage tank and modulates its flame to match flow rate and needed temperature gain. When incoming water from the storage tank reaches the boiler's temperature setpoint, the gas burner does not fire at all.

Heat Storage & Distribution

The same hot-water storage tank is used for both the solar and wood-fired heat sources. Typically, a 1,000-gallon concrete septic tank, buried under the basement floor slab, is a preferred alternative because it doesn't take up floor space. But at Guy and Maria's house, a thick layer of granite, just inches under the foundation depth, made that impossible. We set the tank in a corner of the basement, reinforced its perimeter with a poured concrete wall, and insulated the sides and lid. We also lined the tank with an EPDM (synthetic rubber) membrane to prevent leakage.

Water in a tank that size can absorb 8,060 Btu per 1°F temperature rise. Using a typical temperature rise of about 50°F on a peak solar day, the tank is able to store about 400,000 Btu. For most months of the year, water in the tank will stay between 120°F and 140°F. During colder months with less sun, the SHW system and masonry heater together keep it between 80°F and 110°F. At the top of the tank, heat exchangers draw off the stored water's heat for domestic purposes and hydronic space heating.

Radiant Heating

When space heating is needed, warm water from the storage tank is routed through polyethylene tubing ($^5/_8$-inch PEX) embedded in the thin slab of concrete that was poured over a wood-joist frame on the first floor. Radiant heat works more efficiently with a large mass, which also helps retain direct solar radiation and tempers the building's temperature in the summer, reducing cooling loads.

Upstairs, a thin-slab floor in the bathroom also has hydronic tubing installed. Less temperature stratification occurs with radiant heating systems, so minimal heating is required for upstairs rooms. "The system has worked well and has made a great impact on our comfort and peace of mind," says Guy.

Power From the Sun

Besides relying on renewable resources for space and water heating, Guy and Maria also wanted renewably generated electricity. Their decision to install a PV system was, according to Guy, "in part due to the rebates from Focus on Energy and because we felt it was a start to a self-sufficient home." The roof overhang provides summer shading for upper windows and accommodates a 2,400-watt array of Kyocera PV modules. The overhang's 45-degree angle is close to ideal for this location, maximizing year-round PV production and providing an inconspicuous mounting surface.

Originally, the PV system was expected to cover about 50% of the Janssens' predicted annual electricity usage,

producing an average of 3,120 KWH per year. But with high efficiency appliances, exclusive use of compact fluorescent lighting, an excellent daylighting strategy, and—most importantly—a family that pays adamant attention to energy conservation, the Janssens are consuming much less electricity than predicted. According to Guy, "Over a six-month span during the fall and winter, we used a total of 630 KWH [of utility power]. Our expectations are that we will break even with our system's annual production of electricity compared to our annual usage."

The Janssens' ultimate goal is to become a net zero-energy household, but they still have some improvements to make before they can wean themselves from fossil fuel. Their boiler, range, and clothes dryer use propane gas. Although propane use decreased their electricity use, they still use about 300 gallons annually. Guy says that they plan to "bring this usage down by living with and knowing the system better in the future."

Green-Built

In keeping with their quest to build a resource- and energy-efficient home, the Janssens wanted to use as many local, long-lasting, and high-performance building materials as possible. They were aware of sustainably harvested, rough-sawn white pine exterior siding and shiplap sheathing available from the Menominee tribal forest in Wisconsin, and wanted to use this for their home. Lumber sheathing on the exterior is less susceptible to water damage than particleboard or plywood, and all construction scraps can be safely burned in the masonry heater. Vertical pine siding, with proper flashing and overhangs, can last a century or so with minimal maintenance. It also can be installed unstained, saving money and avoiding the environmental hazards of wood preservatives and stains.

Wood siding was used in the interior to avoid the off-gassing issues that plywood and particleboard have. Inside the home's walls, spray-on and free-blown cellulose insulation containing recycled material was an appropriate and effective insulation choice. Spray cellulose is more effective than fiberglass or other batt insulation because it consistently fills all the voids in a wall cavity. The disadvantage is that it takes a fairly sophisticated machine to apply correctly, costing about 50% more per square foot than fiberglass batts.

We chose steel roofing for its durability and longevity. Compared to petroleum-based shingles, standing-seam metal roofs have four times the life span at less than twice the cost. And when shingles are replaced, the debris is usually sent to the landfill, while steel can be recycled at the end of its useful life.

Solar collectors provide hot water for the house.

The house's framing is standard 2-by-6 stick-type with interior strapping added to create 7-inch-thick walls. The dropped sidewall framing technique addresses the typically poorly insulated area in conventional framing where exterior walls meet the floor.

Our framing materials are not yet certified "green," but we are working with local mills to eventually provide native red pine as a sustainable alternative. Building codes in Wisconsin require that framing lumber be graded, and the small local mills cannot yet absorb the cost of an on-site grader.

Interior walls were finished with naturally tinted earth clay, adding about 2 tons more thermal mass than standard drywall to help moderate heating and cooling swings. Earth-clay plaster also provides a breathable wall surface, which tempers humidity in the house. These wall finishes and the acid-etched concrete floors have high aesthetic value, and pay off because they are more durable and require less maintenance.

Enjoying the Process

The Janssens say they are very pleased with how everything turned out. "There were no major surprises, and we have no regrets," says Guy. "We would do it the same if we had to do it all over again, although I would devote more time to enjoy the building process, and take many more coffee breaks and listen to the birds sing." Now he has the perfect home in which to do just that.

Access

Jim McKnight (jim@gimmeshelteronline.com) and partner **Mark Klein** have designed and built homes as Gimme Shelter since 1987. They are nationally recognized by the National Association of Home Builders for innovative, cold-climate construction methods, and by the Wisconsin Energy Star program for having performance ratings in the top 1% of builders. They are charter members of the Wisconsin Green Building Association and present workshops on sustainable building for the Midwest Renewable Energy Association and other organizations. **Laura Lee** was office manager at Gimme Shelter until the summer of 2007 and continues to write and edit Gimme's Web site. She has a graduate degree in construction management.

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Photovoltaic Systems Co. • 715-824-2069 • pvsolar@wi-net.com • PV system design & installation

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Bob's Plumbing & Heating of Central Wisconsin • 715-824-3902 • Tank heat exchanger fabrication

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NITI • www.nythermal.com • Boiler

Kyocera Solar Inc. • www.kyocerasolar.com • PV modules

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Pumping Water with the Wind

MODERN HISTORIC TECHNOLOGY

by Kevin Moore

Illustrations courtesy of Tom Conlon

It never fails. Whenever I install a new windmill, I can almost guarantee that it will be referred to as an old windmill. When I assure people that it is newly manufactured, the doubt is apparent. "Surely it has been modified to be more efficient," is a standard comment. "Not really," is my answer.

There's no need to reinvent the water-pumping windmill. It's a workhorse that has been mostly unchanged since before World War II. About one million windmills are pumping water in the world today. The most common application is to install a windmill directly over a drilled or dug well. Pumping water from an aboveground source is also an easy task for a windmill. If you need to pump water on your property and the site has access to reliable winds, a water-pumping windmill may be a good option.

Courtesy Kevin Moore

A water-pumping windmill supplies water for cattle that graze under large wind turbines in northern California.

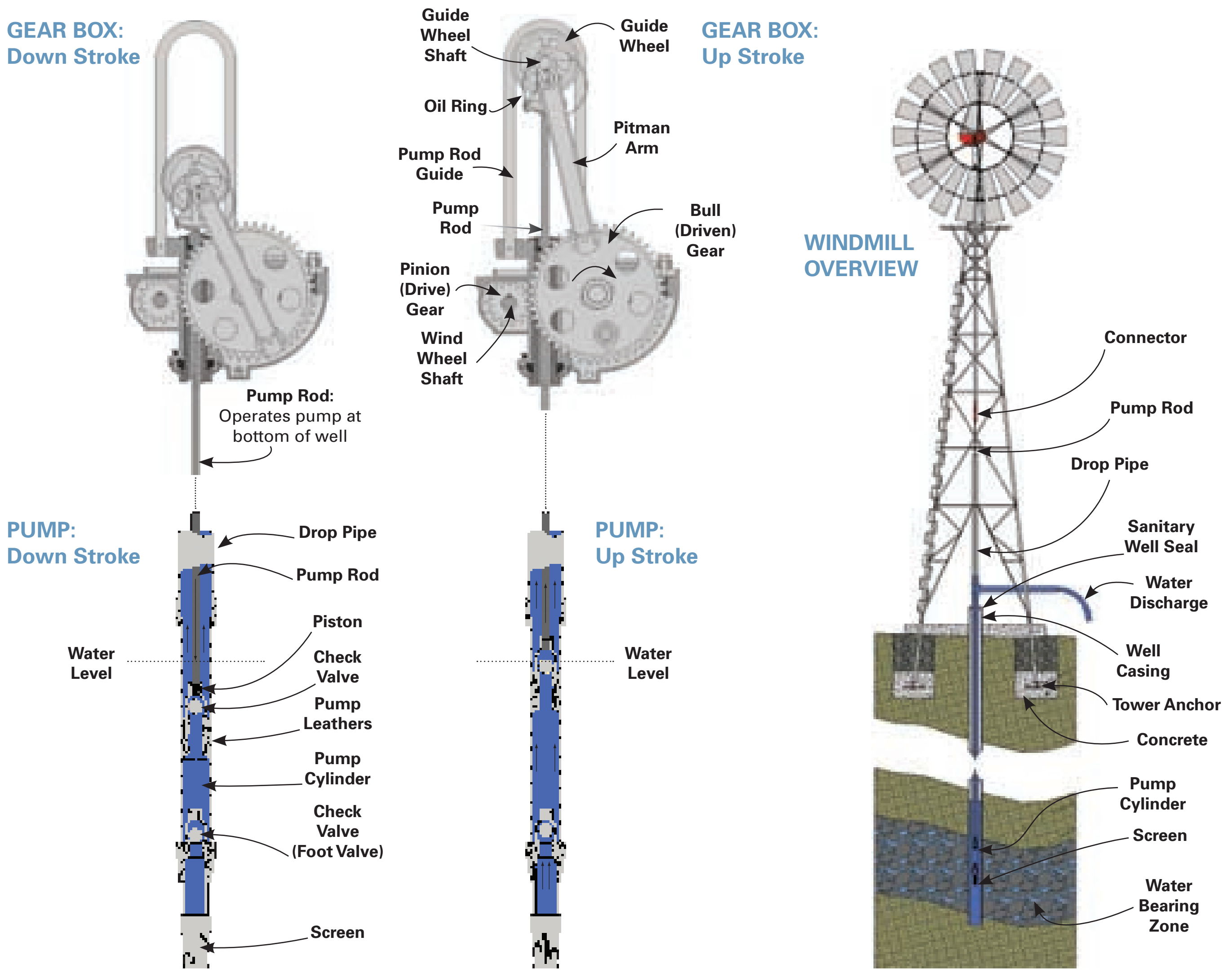
Courtesy Rick Gurries

The author lifts the sheet-metal covering to expose the pumper's gearbox.

How It Works

Water-pumping windmills are simple devices. I always enjoy pulling the sheet-metal cover off the gearbox and letting folks see just how a windmill works. I encourage them to spin the hub and watch the internal parts interact. I've heard the action of a windmill motor described as "using a big wheel for leverage, like the steering wheel on a big pirate ship." People also liken it to "a big jack that lifts water."

No matter how you describe it, the water-pumping windmill is a simple machine that uses mechanical advantage in multiple ways. It's a direct-drive device that transfers energy via gears, rods, simple valves, and a piston in a cylinder—and uses high torque to move water. In contrast, wind-electric turbines use electrical generators coupled to high-tech airfoils that require high speed to do their job.



Illustrations courtesy of Iron Man Windmill Co. Ltd. ©1977 Iron Man Windmill Co. Ltd.

This difference becomes evident when you compare the eighteen or so large blades on windmills to the two or three sleek blades on wind-electric turbines. The wide blades on the water-pumper are designed for low start-up wind speeds and slow-speed operation, as opposed to the electrical generator's thin blades, which are designed to run at higher rpm.

The blades of the windmill wheel catch the wind—just like the sails on a sailboat—which turns the wheel (rotor). The wheel is attached to a shaft by long arms. The shaft has small pinion gears at the other end, inside a gearbox. The pinion gears drive larger bull gears, which move pitman arms. The pitman arms push a sliding yoke up and down, above the bull gears (much like a crankshaft, connecting rod, and piston in a standard vehicle engine). The moving yoke lifts and drops the pump rod to do the work down below.

The pump rod goes down the tower through a watertight seal at the top of the well's drop pipe, and to the pump cylinder, the part that moves the water. The cylinder is attached to the bottom of the drop pipe below the water level, and has a simple piston and two check valves.

As the piston rises, water moves up the pipe above it. At the same time, water is sucked through a screen and the lower check valve below the piston, into the lower section of the pump cylinder. When the pump rod reverses and begins to descend, the lower check valve closes and the piston check valve opens. This allows water in the cylinder to pass through, and the water that is trapped above the piston to be pushed up out of the cylinder and ultimately to its final delivery height. One might think of the pump as a cup with a trap door in the bottom that opens when the cup falls and shuts when the cup rises. This cycle is constantly repeated as the wind wheel turns to move the pump rod up and down.

If the wind wheel is moving, the pump piston is moving. As the wind speed increases, the speed and frequency of the piston stroke increases, so more water is pumped. But the windmill's efficiency drops because the airfoil is not optimized for higher wind speeds—it doesn't make as much use of the cubic effect of wind power as a wind generator does. (The power available in the wind is proportional to the cube of the wind speed.) But then, water needs do not increase in proportion to the wind speed either, so this is not a major impediment. In fact, water pumpers do the job they are designed for efficiently and well.

Siting Your Windmill

To avoid turbulence caused by surrounding objects, the blades of water-pumping windmills should be at least 30 feet above any obstructions such as trees or buildings in a 300-foot radius. Access to "clean wind" helps the windmill operate smoothly, ensures a more effective operation, and extends its life. This often means installing a tall tower, so you can get well above nearby buildings, trees, and land features.

Although you can select and site a windmill without using local wind-speed data, correctly sizing the windmill and pump cylinder (see How Much Will it Pump?) using real data will remove much of the guesswork about how much the 'mill will pump. A well-selected and well-sited windmill should start pumping water at wind speeds between 6 and 8 mph. Most windmill manufacturers rate a windmill's pumping capacity for winds in the 10 to 20 mph range. You should be practical—don't size the windmill at its peak pumping capacity, or as if it's only going to experience high winds.

Courtesy Tom Marvin

The author inspects a new gearbox.

Sizing Considerations

Before you choose your windmill, you must know the water level in your well. It doesn't matter how deep the well is—it's the static level of the water and the vertical distance the windmill needs to lift the water that is important. You also need to know if the water level changes seasonally, or if the water level "draws down" or falls below the static level when water is pumped.

Unless you know how to make the wind blow on demand, you also will need storage for the water that is pumped. For water storage, I've used everything from plastic barrels to ponds. The best method, if you have enough height to create sufficient pressure (about 70 feet of vertical drop will give 30 psi, which is suitable household pressure), is to locate a storage tank above the point of use, and gravity-feed the water from there.

Once you've determined the vertical distance your 'mill needs to lift water within the well and the additional vertical lift to the storage tank, you can investigate your windmill options based on the amount of water you need and your budget. Here's an example: If the lowest water level in the well is 60 feet below ground and you need to lift water to a tank that is 20 feet above the well, the total lift is 80 feet. Using the Pumping Capacities table, you can find what size windmill to use, as well as correctly determine the cylinder diameter to use.

How Much Will It Pump?

The amount of water your windmill can pump is regulated by the size of the pump cylinder, the elevation to which the water needs to be raised, the size of the wind wheel, and how much wind you have at your site.

A typical windmill with an 8-foot-diameter wheel can lift water 185 feet and pump about 150 gallons an hour in

Protection from High Winds

When you are working with Mother Nature, you soon realize that she will try to destroy anything you dare to use to harness her wind. From large wind-electric turbines to farm windmills, wind machines must be robust and have a means to protect themselves from high winds.

The typical water-pumping windmill uses an off-center mast pipe and an oversize tail vane to turn the blades out of the wind (furl) at high wind speeds. An adjustable spring is used to select the speed control point to furl the windmill out of the wind and to return the windmill into the wind as the wind speed decreases. Windmills are also equipped with a lever at the tower base to manually turn the windmill out of the wind and set a friction brake.

Windmill shown "furled," or turned out of the wind (blades are parallel to the tail).

Courtesy Kevin Moore

Pumping Capacities*

Cylinder Diam. (In.)	Capacity (Gal. / Hr.) at All Wheel Diameters	Pumping Elevation/Lift (Ft.) @ Wheel Diameter 8 Ft.	10 Ft.	12 Ft.	14 Ft.	16 Ft.
1.75	150	185	280	420	600	1,000
1.88	180	175	260	390	560	920
2.00	190	140	215	320	460	750
2.25	260	112	170	250	360	590
2.50	325	94	140	210	300	490
2.75	385	80	120	180	260	425
3.00	470	68	100	155	220	360
3.25	550	58	88	130	185	305
3.50	640	50	76	115	160	265
3.75	730	44	65	98	143	230
4.00	830	39	58	86	125	200
4.25	940	34	51	76	110	180
4.50	1,050	30	46	68	98	160
4.75	1,170	–	41	61	88	140
5.00	1,300	25	37	55	80	130
5.75	1,700	–	–	40	60	100
6.00	1,875	17	25	38	55	85
7.00	2,550	–	19	28	41	65

*At 15 to 20 mph wind speeds; Based on long stroke. For short stroke, reduce capacity by 25% and increase elevations by 33%.

15 to 20 mph winds when using a 1 3/4-inch pump cylinder. The size of the wind wheel and pump cylinder impact the maximum lift that's possible and the volume of water that can be pumped, respectively. A bigger wind wheel can lift water higher than a smaller one, and a larger cylinder pump can deliver a greater volume of water. If we increase the size of the pump cylinder to 3 inches while still using the same 8-foot-diameter wheel, the volume delivered increases to 470 gallons per hour, but the maximum lift decreases to 68 feet. If we stay with that 3-inch cylinder, but increase the windmill to a 16-foot diameter wheel, we will be able to deliver the same 470 gallons a total of 360 feet.

The above examples use a windmill configured in the standard (long-stroke) mode at wind speeds between 15 and 20 mph. Most windmills have the ability to change the length of the stroke of the pitman arms. At the same wind speeds, but in the short-stroke mode, the windmill will pump at lower wind speeds, but will pump less water.

Windmills are made with wheel diameters ranging from 6 to 20 feet, although the most common size wheel is 8 feet in diameter. Add a 33-foot steel tower to it and the cost is about $4,000 (windmill: $2,100; tower: $1,900). A 20-foot-diameter wheel windmill with a 50-foot-tower will cost close to $25,000. If you're still unsure how to choose the right windmill for your site, don't worry—most windmill suppliers will be happy to help size the windmill and pump cylinder correctly.

Installation

With sharp edges on 18 sheet-metal blades and a sizable heft (a complete 8-foot windmill weighs about 350 pounds), installing a windmill can be very awkward at best, and outright deadly without proper training and equipment.

Rescuing Used Windmills: Buyer Beware

Courtesy Bryon Rykard

In many parts of the world, old windmills can be found resting idle in the fields. A once-proud but now lonely windmill standing on a tower can be a temptation for many of us. As the wind blows, the motionless windmill seems to call out to you with a squeak or even a painful whimper, just as the Tin Man called to Dorothy in the *Wizard of Oz.* Oil, you think, just a little oil and that windmill will run again.

But in the world of used pumpers, a fine line exists between the "do-it-yourselfers" and the "do-it-*to*-yourselfers." Compare that old windmill to an old car. Would you buy a 1940s-era car that's been weathering the elements for decades and expect to drive it every day? More than likely, that windmill has been standing on top of its tower, exposed to the weather, every day of its life—for decades. Do you think that its owner diligently changed the gearbox oil every year since 1940?

Most abandoned windmills have been damaged beyond repair during years of disuse. Common points of failure or damage in an old windmill include the soft metal (babbitt) bearings, which need to be poured in place, not simply replaced with a kit. Every shaft hole is mostly likely out-of-round, and moving parts have worn due to lack of oil. Structural failure could be one broken bolt away. Windmill gearboxes are typically cast iron, and are balanced by the even distribution of weight. Once one part fails, other parts are unequally loaded and stressed by the failure.

Even if you find a well-preserved and well-maintained 'mill, you still need to remove and transport it. Putting up a windmill can be very dangerous—taking down an old windmill is *always* dangerous, and is not work for the uninitiated. It requires skill and experience in climbing, rigging, and dealing with large, heavy objects, and a sixth sense about the condition of the used tower and mill.

So if you're thinking about salvaging an old windmill that's been sitting in your neighbor's field for decades—just stop. Many folks have tried before you, and the relic usually ends up joining the other tired windmills tucked away in the garage corner after someone finally figures out that they'll be money ahead investing in a new one.

Professional installers can be found in almost every region of the United States, or a windmill and tower can be assembled and erected by most do-it-yourselfers who take a one-day class (see Access). Some people choose to erect the windmill and tower without the benefit of a boom truck or lift, though this is not recommended.

For well installations, it is important to center the windmill directly over the well. Any bending or flexing of the pump rod will lead to excess friction and early failure of the moving parts. Also make sure that the top of the tower is level when the installation is complete. All windmills are designed to rotate on the tower axis to face into the wind. If your tower is not level, your windmill will turn downhill when the wind is calm and will not return to face the wind as easily.

Servicing the Windmill

The one major improvement in the 150 years that American windmills have been made was the introduction of the self-oiling windmill in the 1930s. Before that, a windmill's parts had to be lubricated weekly by climbing the tower to grease the moving parts. But even with this advancement, windmills still require regular maintenance to keep them working well.

The instructions that a windmill manufacturer would have offered 75 years ago still apply today:

- Always keep an eye and an ear toward your windmill. Peculiar sounds or visible abnormalities should be investigated at once.
- Once a year, change the oil.
- Twice a year, check the nuts and bolts. Tighten any loose fasteners, and replace any that are rusted or damaged.
- Water-pump seals should last five years or more, unless your water contains lots of sand or grit, which will shorten seal life. A good filter on the bottom of the pump will help alleviate this problem.

Courtesy David Martin

The author installing a 10-foot-diameter windmill.

Gearbox Care

Many good windmills have been destroyed by using the wrong oil. Each windmill company will specify the correct oil for their gearbox. Most use a 10-weight or very light nondetergent-type oil. The thin oil travels easily to the many moving parts. Nondetergent oil allows any contaminants to fall to the bottom of the gear case. Adding detergent oils will cause build-up and contaminants to block small oil ports. Once the ports become blocked, the lack of oil to the bearings will lead to major failures.

Repair any damage you spot during your semiannual maintenance check to help ensure that your windmill will keep pumping water for decades.

Windmills: Yesterday & Tomorrow

At one time, water-pumping windmills were a common sight on the American landscape. It wasn't until the 1936 Rural Electrification Act, which provided cheap electricity to almost every home, that windmills were replaced by electric pumps. But water-pumping windmills haven't died—and as people search for simple, reliable, and renewable solutions in our complicated world, these pumpers are experiencing a renaissance.

So if you need to pump water and you have a suitable wind site, think about using this modern historic technology. But be prepared for people to ask you, "Is that an old windmill you just put up?"

Access

Kevin Moore (www.rockridgewindmills.com) is a water-pumping windmill enthusiast and owner of Rock Ridge Windmills in northern California. He has worked on windmill projects from rural China to the American Midwest, and teaches water-pumping windmill classes at the Solar Living Institute in Hopland, California.

Tom Conlon (www.ironmanwindmill.com) was in the windmill business in California for many years. Today, he manages a windmill factory in central China where he functions as an unofficial American ambassador of goodwill, while working to introduce American agricultural technology to help improve living conditions in poor rural farming villages.

Water-Pumping Windmill Manufacturers:

Aermotor Windmill Inc. (Texas) • 325-651-4951 • www.aermotorwindmill.com

Dempster Windmills (Nebraska) • 402-223-4026 • www.dempsterinc.com

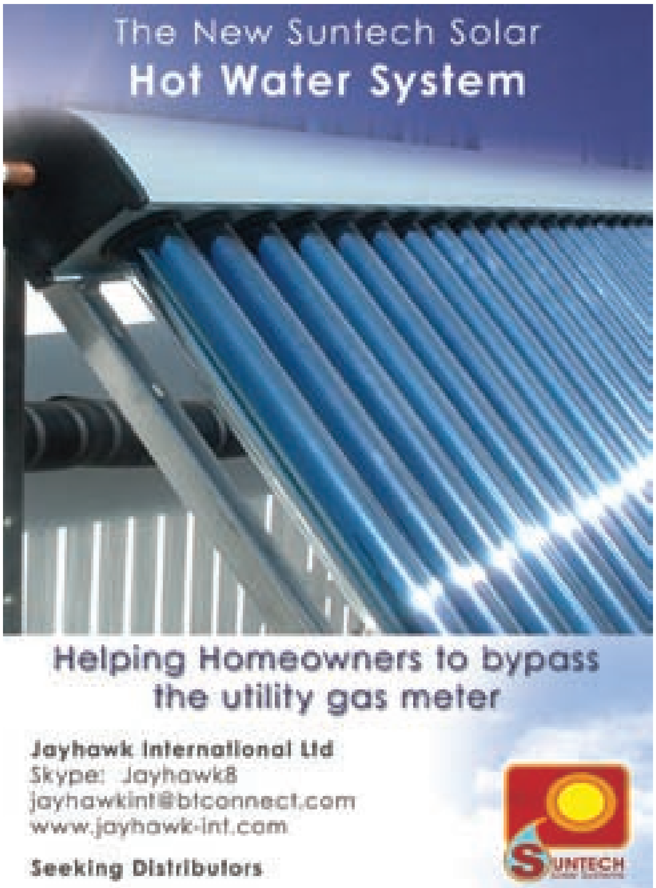
Iron Man Windmills (China) • 86-27-8349-6716 • www.ironmanwindmill.com

Southern Cross Windmills (Australia) • 61-07-131-786 • www.southcross.com.au/windmills

Water-Pumping Windmill Classes:

Solar Living Institute • 707-744-2017 • www.solarliving.org

University of New Mexico, Carlos Rosencrans • 505-646-4511 • crosencr@nmsu.edu • www.nmsu.edu



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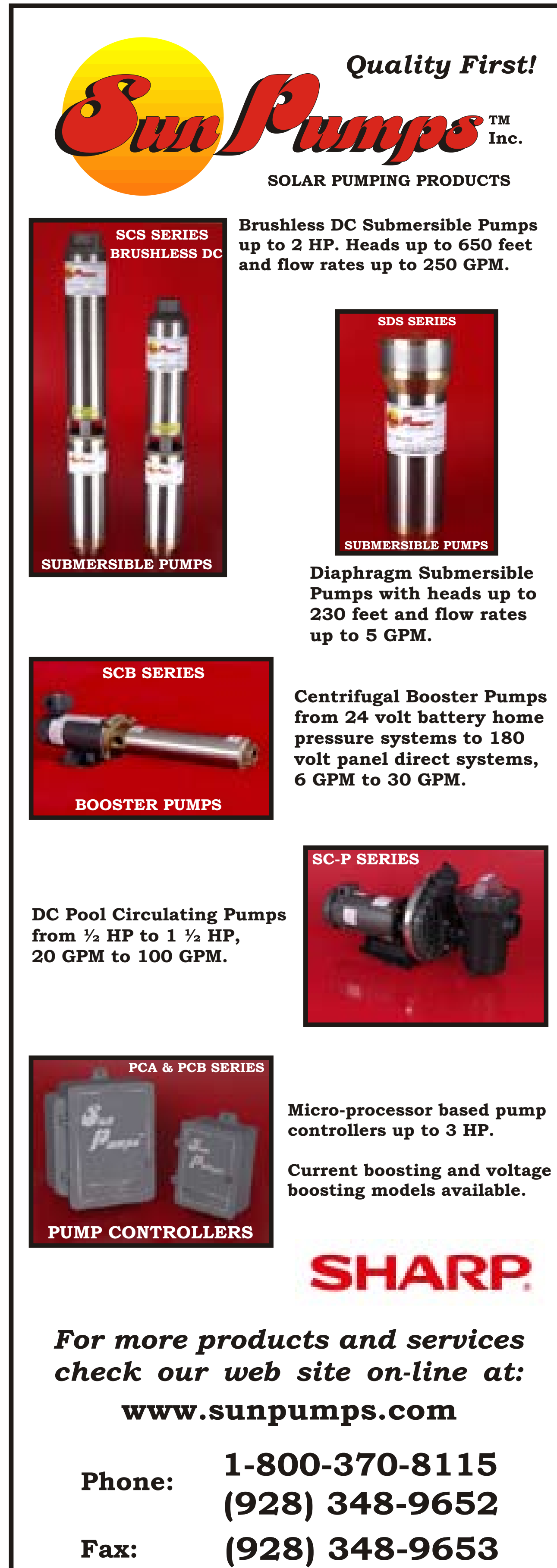

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Go with the Flow

Passive Solar Biodiesel Storage

by Lyle Estill & Stephen Hren, photos by Tami Schwerin

Tami Schwerin fills the tank of her diesel Mercedes with biodiesel from Piedmont Biofuel's solar straw-bale shed.

Cold weather is the Achilles' heel of biodiesel-fueled vehicles, congealing the fuel to a sludgelike consistency, and clogging fuel lines, filters, and injectors. While onboard heaters in your vehicle can warm the fuel and keep your rig rolling, that only solves half the problem. Cold temperatures can slow the flow at the pump as well, creating a jam for biodiesel home brewers and dispensers who need to keep their fuel flowing through the winter.

Fortunately, there are options: These easy-to-build, passive solar sheds keep stored fuel warm and flowing—and the best part is, they do it without any additional energy costs. The buildings come with an added bonus—if your plans change and you end up not using the structure for fuel storage, you can still use the space for a garden greenhouse or whatever solar scheme you dream up next.

Chill Factors

Although winter temperatures in the Piedmont region of central North Carolina aren't typically frigid, they do sink into the teens, causing problems for our biodiesel fuel co-op, Piedmont Biofuels, which distributes 100% biodiesel (B100) to its members.

As ambient temperatures plunge, microcrystal waxes start to form in the fuel. Large crystals precipitate and eventually settle to the bottom of the tank or storage barrel. The lower the temperature drops, the cloudier and thicker the fuel gets. A fuel's gel point is the temperature at which the fuel freezes and can no longer be pumped or poured. B100 made from new vegetable oil typically has a cloud point (the temperature at which waxes form) of 32°F and starts to gel at 20°F. Biodiesel made from different feedstocks will cloud and gel at different temperatures. (In comparison, petrodiesel typically has a cloud point of 20°F and a gel point of 0°F.)

Winterization methods for pure biodiesel come in many forms. During colder months, some biodiesel users add winter petrodiesel to make a B50 blend with a lower gel point. Others install in-line fuel heaters in their vehicles or plug in their electric engine block heaters overnight. Another, albeit fuel-intensive, method to keep biofuel from gelling is to keep the rig in a heated garage.

Passive Solar Solutions

As a B100 provider, we wrestled with cold-flow fuel pumping issues for several winters. Because our co-op tends to be supported by sustainability addicts who strive to fuel their lives with as little petroleum as possible, winterizing our B100 with petrodiesel was not acceptable. We also were interested in keeping within our mission of leading the sustainability movement in North Carolina, which meant keeping our energy inputs low.

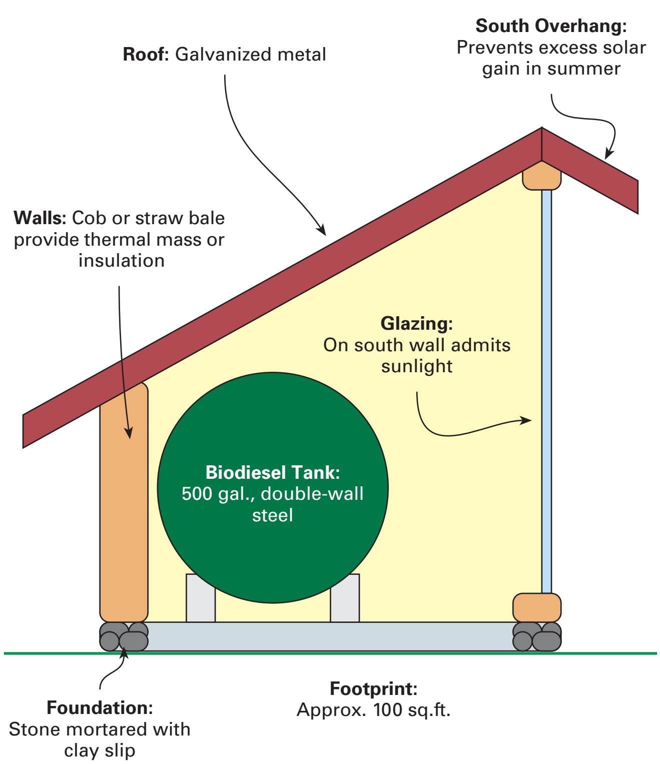
The answer to our dilemma was to design around the problem—literally—so we planned a passive solar storage structure that would heat itself with the sun's energy. Our

previous cob construction experience (see "A Hand-Built Home" in *HP112*) and access to an abundance of red clay made the decision to build a cob greenhouse a natural choice. We purchased sand and straw from the local lumberyard, and rescued lumber and tin roofing from an old shed that had originally sheltered our 500-gallon biodiesel fuel tank. A glass door and window were hiding nearby in the co-op's boneyard, waiting for a new home. All told, the materials cost just a few hundred dollars.

We figured that incorporating enough thermal mass—including the tank—into a south-facing structure with adequate glazing could keep the biodiesel above its gel point throughout the winter. We wanted the shed to be big enough to allow access around the tank, but small enough (less than 144 square feet) to count as an agricultural building and not need a building permit. We finally settled on a design that would give us a 100-square foot building, with 1-foot-thick cob walls.

The thick walls of the passive solar cob shed provide thermal mass, helping moderate temperature swings inside the building.

Storage Shed Basic Components



Creating with Cob

Using recycled and local materials helped ensure that the construction of the shed would have a small environmental footprint. A group of co-op members provided labor in exchange for the opportunity to learn how to build with cob. Together, a half dozen of us accomplished the construction in a series of Sunday afternoon workshops after the weekly lunch potluck.

First, we laid landscaping cloth and then tamped gravel to establish a base. Hand-stacked stone, filled in with slip-straw (straw dipped in a water-clay slip), serves as the perimeter foundation. For the cob walls, sand and clay, mixed in a 2:1 ratio, were thrown into a churning cement mixer, watered to the appropriate consistency, and allowed to spin for a minute or so before a few handfuls of straw were added. The finished mix was applied to a slowly growing wall. In appropriate places, lumber was keyed into place for attaching windows and doors.

Cob's trade-off is that it takes lots of human energy and time. Obtaining and mixing the materials is a slow process, and building up the walls will exercise your muscles—and patience. After about three months of Sunday cobbing, we were ready to put on the roof and frame in the door and windows. During the weeklong intervals between the cob sessions, we covered the walls with several layers of tarps to prevent the walls from drying out too much, which could have compromised the bond between the individual layers of cob.

Despite the up-front work, the finished material has benefits—cob is slow to take up water, slow to degrade, and, most importantly for our purposes, slow to change temperature. With no supplemental heating, the building achieves a constant 20-degree delta T—a difference of 20°F between the ambient (outside) temperature and temperature of the biodiesel in the storage tank—which has suited our

fuel-storage strategy very well. Even on 18°F mornings, our fuel is at a cozy 38°F, and flowing nicely.

Initially, we'd considered insulating the north side of the cob greenhouse, either with straw bales or even with used telephone books. This would have improved the building's thermal performance, but ultimately, the biodiesel in the tank and the cob walls provide enough thermal mass to store the sun's energy overnight. For our purposes and climate, additional insulation wasn't necessary, but it may be essential in colder locations.

Biocompatible Bales

As the co-op and demand for biodiesel grew, so did our need for more fuel storage. Although the cob structure performed well and was inexpensive to construct, we needed to be able to build a place for our next solar-heated biodiesel tank in a few weekends instead of a dozen.

We still wanted to hold on to our original criteria of using locally available and salvaged materials to build an inexpensive passive solar shed, and a combined straw bale/stick-frame construction approach fit the bill. For the wall structure, we used leftover pressure-treated lumber donated by a local deck builder and insulated it with straw bales from a local farm. What straw bales lack in thermal mass, they make up for in insulation value, about R-2 per inch. For greenhouse applications, straw bales are a great fit. The material is easy to use and effective. Covered with an earthen plaster, it's also beautiful.

But beauty is in the eye of the beholder. Built within the city limits, the straw-bale structure proved to be a thorn in the side of local building and fire regulators, who were specifically concerned about the potential hazards of storing 500 gallons of biodiesel inside a straw bale structure. Although inspectors could not find any code references to bring down our straw-bale shed, we allayed their biggest concern by finishing the inside of the shed with drywall. This satisfied the inspectors, who finally signed off on the building, giving us the first legal straw-bale storage shed for biodiesel in North Carolina.

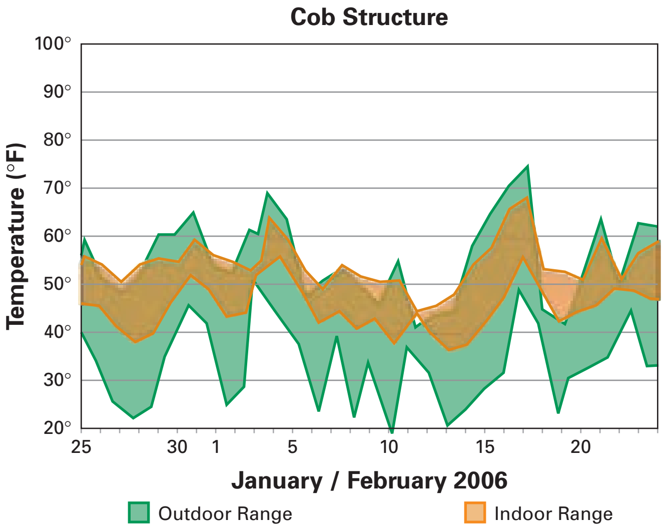
Even with the additional work of sheathing the interior, this project only took two people four days to complete. With hired labor, the associated expense—about $1,000—was significantly more than the cob shed's entire construction cost.

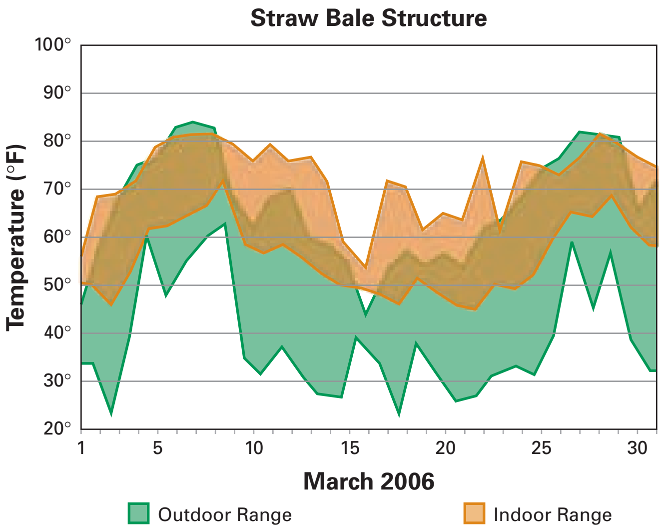
Passive Performance

To satisfy his inner nerd and prove to skeptics that inexpensive, simple solar sheds made of wood, straw, and clay can offer good performance, co-op member Don Mueller monitored temperatures inside both structures with a datalogger. On average, the straw-bale shed manages to keep stored biodiesel about 25°F above ambient temperatures; the cob structure generally maintains biodiesel about 20°F above outside temperatures. The sun also provides another function for each off-grid fueling shed: A 20-watt PV module charges a 140 amp-hour battery bank, which provides power to a 12-volt fuel pump.

Though we're quite proud of our little operation, we have no interest in becoming the next Rockefellers of biodiesel. Our goal is to meet our co-op members' fuel needs with feedstock that we have on hand. Presently, we meet the transportation fuel needs of about 300 families, with the average member using about 45 gallons of biodiesel per month. Tapping into the sun not only makes this possible—it makes it practical, and keeps our fuel flowing and customers happy. B100 users pull up, grab a fuel nozzle, fill up, and are back on the road in no time flat.

Building Performance





Access

Stephen Hren (themudranch@yahoo.com) is a teacher, writer, and carpenter living in Durham, North Carolina. He is currently working on a book with his wife Rebekah called *The Carbon-Free Home: 36 Ways to Kick the Fossil Fuel Habit*, to be published by Chelsea Green in the spring.

Lyle Estill (lyle@biofuels.coop) is a founder of Piedmont Biofuels, and is currently an active board member. He is the author of *Biodiesel Power: The Passion, the People, and the Politics of the Next Renewable Fuel* (New Society, 2005). He is the publisher of the widely read Energy Blog, which can be found at www.biofuels.coop.

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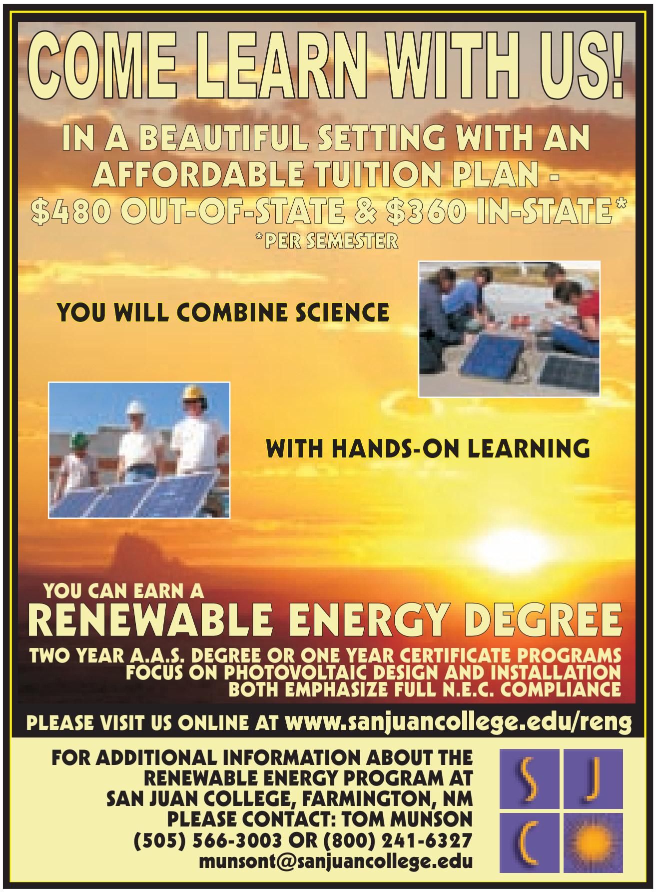
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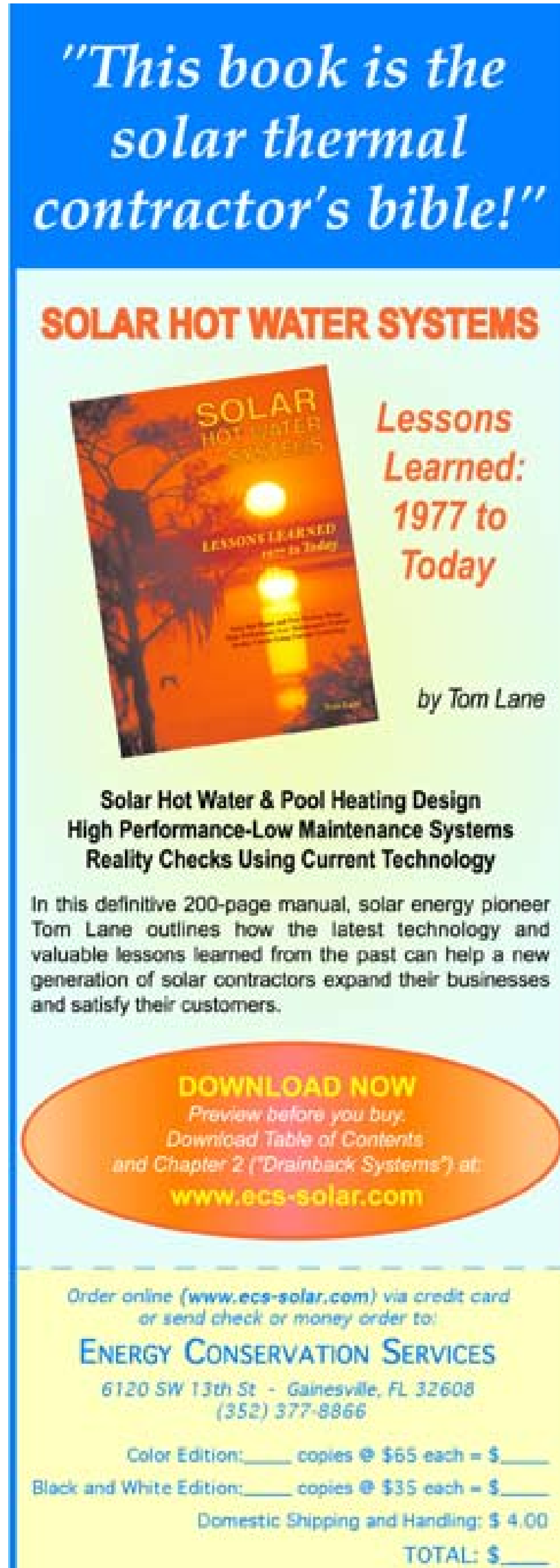
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Module Wiring 101

by John Wiles

Sponsored by the U.S. Department of Energy

Photovoltaic systems require wiring methods not normally found in residential or commercial electrical systems. Do-it-yourselfers and installers alike should become familiar with the *National Electrical Code (NEC)* sections that pertain not only to PV systems but to electrical systems in general, and become confident in distinguishing the basic types of conductors and knowing their proper use. While conceptually simple, joining PV modules together and making the connections to the rest of the system's components should be carefully done with a solid working knowledge of electrical systems.

PV Wiring & Conductor Types

Usually, single-conductor, exposed cables are used to connect individual PV modules in the PV array, a technique permitted by Section 690.31 of the *NEC*. Conductors permanently attached to the PV module are part of the listed module assembly and have been certified by Underwriters Laboratory (UL) as meeting the necessary safety requirements. In most cases, the cables are marked USE-2 or USE-2/RHW-2. Some are also marked "Sunlight Resistant," indicating better ultraviolet light resistance than the basic USE-2 cable, which is tested for UV resistance but not marked as such.

PV modules are typically connected in series strings. After making several connections, the positive and negative conductors at the ends of each string lie some distance apart. To bring these two points to a common location, a single conductor is used. Although Section 690.31 of the *NEC* allows USE, SE, and UF cables, installers typically use a USE-2 or USE-2/RHW-2 cable to bring the negative and positive negative conductors to the same spot. Because PV modules may heat up to 80°C (176°F), wiring touching or near the backs of modules should have 90°C (194°F)-rated insulation. In outdoor applications, "-2" conductors (USE-2, RHW-2, THWN-2) also should have a 90°C, wet–rated insulation, whether they're exposed or run in conduit.

The cable may be purchased with matching connectors attached, or a cable and connector may be assembled if the necessary crimping tool and required factory training are available. At this connection point, which must be under or very near the array, the exposed conductors are transitioned, using a junction box, to one of the common wiring methods stipulated in Chapter 3 of the *NEC*.

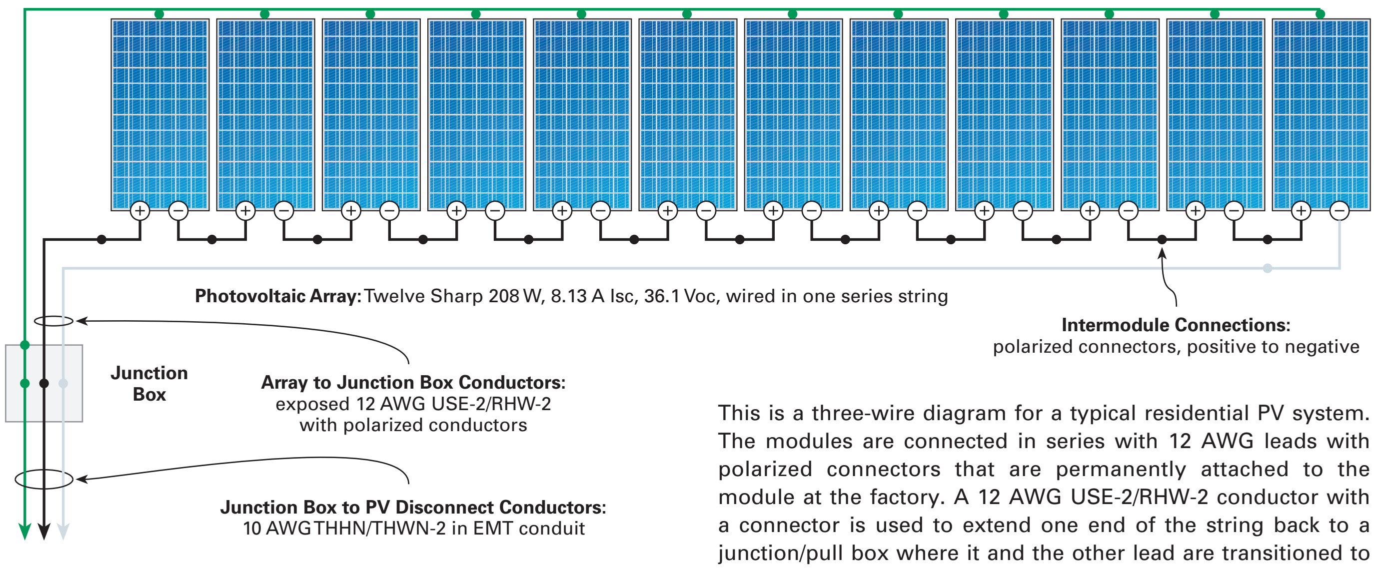
Where exposure to the weather is possible, especially in hot and wet conditions, THHN/THWN-2 or RHW-2 conductors are typically installed in conduit. Electrical metallic tubing (EMT) is commonly used, and, where allowed by local codes, rigid nonmetallic conduit (RNC) may be used. However, in very hot climates, the plastics used in RNC may not age well. In some cases, liquid-tight flexible nonmetallic conduit can be used, but is acceptable only when properly attached to the supporting structure. PV output conductors routed through the building to the DC PV disconnect must be installed in metal conduit. Nonmetallic conduits are not acceptable because of their limited fire resistance, lack of ground-fault indication, and lower degree of physical protection for the enclosed cables.

Conductors run in exterior conduit exposed to sunlight on roofs should be given special consideration. For example, in climates that experience average high ambient temperatures of 40°C (104°F), conduit installed on a rooftop can easily reach temperatures of 62°C (144°F). For conductors exposed to these conditions, the *2008 NEC* calls for an addition of at least 17°C (31°F) to the ambient temperature correction. If the conduit is within a half-inch of the roof, the added temperature should be 33°C (59°F). Between 0.5 and 1.5 inches, the temperature added should be 22°C (40°F). To accommodate the reduced ampacity at higher temperatures, appropriate temperature deratings may dictate the use of larger conductors than would otherwise be used. (For more information, see the Fine Print Note #2 for Section 310.10 in the *2005 NEC*.)

For conduit run inside the building, conductors that only bear the USE-2 marking may not be used, since this cable does not contain the required flame and smoke retardants, but USE-2/RHW-2 conductor is acceptable. In the *2008 NEC*, the allowed use of cable types USE, UF, and SE was removed from Section 690.31 due to their temperature limitations and availability in the proper sizes (10, 12, and 14 AWG) for module interconnections.

A new PV conductor—a single-conductor cable designated "PV Wire," "Photovoltaic Wire," "PV Cable," or "Photovoltaic Cable"—will be allowed under Sections 690.31 and 690.35 of the *2008 NEC*. It will be marked "Sunlight Resistant," and will have the necessary flame- and smoke-retardant properties to allow its use in conduit inside buildings. However, this cable also will have thicker insulation than USE-2 conductor, and conduit fill will have to be calculated, rather than by using the tables in Chapter 9 of the *NEC*. This cable will be one of the wiring methods required in PV systems that operate ungrounded and use the new transformerless inverters.

Example of PV Array Wiring



This is a three-wire diagram for a typical residential PV system. The modules are connected in series with 12 AWG leads with polarized connectors that are permanently attached to the module at the factory. A 12 AWG USE-2/RHW-2 conductor with a connector is used to extend one end of the string back to a junction/pull box where it and the other lead are transitioned to 10 AWG THHN/THWN-2 conductors in a 3/4-inch EMT conduit (see *NEC* Section 690.35).

Other PV Parts & Pieces

Module short-circuit currents may range from 1 amp to about 17 amps (in unusual cases). Large (300-watt and greater) PV modules have short-circuit currents approaching 12 amps. The ampacity of the attached and any field-installed cables should be 1.56 times the module short-circuit current (Isc) after the "conditions of use" are applied, which include the external temperature that the cable will be subjected to and any factors associated with the number of conductors in a bundle or in a conduit. In most cases, the factory-attached cables have sufficient ampacity. However, in very hot climates, the conductor temperatures may be so high that the ampacity of the attached cables is insufficient to meet the 1.56 Isc requirement after temperature corrections are applied. The ampacity of these cables should be evaluated using *NEC* Table 310.17.

Equipment-grounding conductors connected to the PV module frames should be sized at 1.25 times the module Isc. On large PV arrays, where fuses are used to protect these conductors, *NEC* Table 250.122 should be used instead for proper sizing. This will result in a smaller, but adequate, equipment-grounding conductor that will be calculated using the 1.25 Isc value.

The backs of all listed PV modules are marked with a "Maximum Series Fuse" value or similar wording. An overcurrent device (fuse or breaker) protects the internal module conductors from damage from overcurrents that could be forced through the module from external sources. Although many residential PV systems do not require overcurrent protection in DC circuits, larger commercial systems usually do because the multiple parallel strings of modules are sources of potentially damaging fault currents. The *NEC* requires that any overcurrent device installed in the output of a module be rated at 1.56 Isc. There are a few modules being made (for unknown reasons) that have a maximum series fuse value of *less than* 1.56 Isc, which poses a code quandary. Section 690.8 says to use a fuse rated at 1.56 Isc, but Section 110.3 says to follow the product labels. Any installer facing this quandary should report the problem to UL via https://www.ul.com/consumers/conproddb.cfm.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to contact me. See the SWTDI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

John Wiles (jwiles@nmsu.edu) works at the Southwest Technology Development Institute, which provides engineering support to the PV industry and provides industry, electrical contractors, electricians, and electrical inspectors with information on code issues related to PV systems. A solar pioneer, he lives in his grid-tied PV-powered home in the suburbs.

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Power Struggles

by Don Loweburg

With hundreds of thousands and even millions of dollars at stake, competition for new energy infrastructure projects is heating up between union and nonunion labor groups. And this is spelling trouble for communities interested in fast-tracking renewable energy-based power plants.

Sacramento Municipal Utility District/NREL

Last summer, an appeal brought forward by the International Brotherhood of Electrical Workers (IBEW) threatened to bring a 2-megawatt solar project at the Fresno Yosemite International Airport to a screeching halt. The appeal, as a July 25, 2007, article in the *Fresno Bee* reported, contended that the project didn't go through a "proper environmental review process, potentially exposing neighbors to dangerous dust and diesel exhaust pollutants" during the project's construction phase. But representatives of the Associated Builders and Contractors (ABC) of California, a nonunion group, said that the union's appeal was a "bargaining chip to secure guarantees that union workers would be hired on the project."

Kevin Dayton, state government affairs director for the ABC, says these actions are typical of what unions have been doing for years whenever a power plant undergoes the licensing process. "We call it *green*mail," he said.

Gerald Zumwalt, business manager for IBEW Local Union 100 in Fresno, sees it differently. In the *Bee* article, he said, "IBEW's position is [that] we're in favor of solar power. But it needs to done right. Every time a project goes in and earth is moved and equipment goes in, air quality decreases."

Zumwalt's position is amplified and supported by the California Unions for Reliable Energy (CURE), a coalition of unions whose members help "solve the State's energy problems by building, maintaining, and operating conventional and renewable energy power plants." But the ABC says that CURE's agenda goes beyond their mission statement and has called for the California Energy Commission's investigation of "abuses of the permitting process by special interest groups with primary objectives unrelated to environmental protection." Their charges? That the union's use of "greenmail has delayed and increased costs of energy infrastructure projects and cut competition in industrial construction contracting."

Stakeholder Squabble

ABC representatives point to the fact that, as an April 29, 2002, article in the *Contra Costa Times* reports, "CURE filed environmental interventions with the California Energy Commission and eventually won labor-friendly agreements for 23 of the state's 24 newly approved power plants." Some RE advocates also put the initial failure of SB1—the California Solar Initiative, the nation's largest long-term solar program, on the IBEW's shoulders, blaming in part the IBEW's proposed pro-union amendments for the failure of the bill passing on its first go-round. A June 30, 2005, editorial in *The Sacramento Bee* said that "solar's future is bright, but in the bowels of the legislature, business remains murky, as usual. There, labor unions are demanding that private contractors pay 'prevailing wages' to workers who install solar panels as part of SB1, the governor's legislation to help provide solar energy to 1 million homes."

Following SB1's initial defeat during the fall of 2005, Ed Hill, president of the IBEW, addressed attendees at Solar Power

2005. During a plenary session, he remarked that "electricity is our business" and signaled IBEW's intention to aggressively pursue solar-electric projects. In spite of their heavy-handed tactics, the IBEW has made some constructive efforts. It has developed training material and learning centers where their members can get the special training needed for installing PV systems. The IBEW National Joint Apprenticeship and Training Committee has also worked collaboratively with the solar industry in establishing credentialing programs and study guides.

The Stakes

Although SB1 finally passed in the California legislature, and the Fresno City Council unanimously rejected the labor union's appeal to halt the airport solar power project, the ABC says that union greenmailing practices are "delaying important projects needed by the public, increasing the costs of projects for developers, and, subsequently, reducing competition in the construction market."

In the *Times* article, Bob Balgenorth, president of the California Building and Construction Trades Council and chairman of CURE, says, "We have never raised an environmental issue where part of the settlement didn't address that issue. And we never would. It makes no sense, and we would lose our credibility with everyone."

The stakes are high—and so are the potential profits. According to the California State Building Trades Council, "Power plant projects provide an average of 750,000 construction [labor] hours of work, and typically obligate the owner to a 30-year maintenance contract." But just as energy production must evolve, so must the business of investment in and the construction of power-generating facilities. Are union environmental interventions serving the public interest or just disrupting and delaying tactics to secure project labor agreements? Are the ABC's objections and allegations of greenmailing founded in fact or just an effort to grab a piece of the profit pie?

As consumer energy demands continue to increase and more PV power plant projects develop, this issue is certain to escalate. Industrial-scale PV projects are the fastest growing segment of the U.S. PV industry, and the potential profits on the table are significant. As such, equal opportunity during projects' competitive bidding is imperative, and will ensure cost-effective installations that best serve the investors, equipment integrators, and the public.

Access

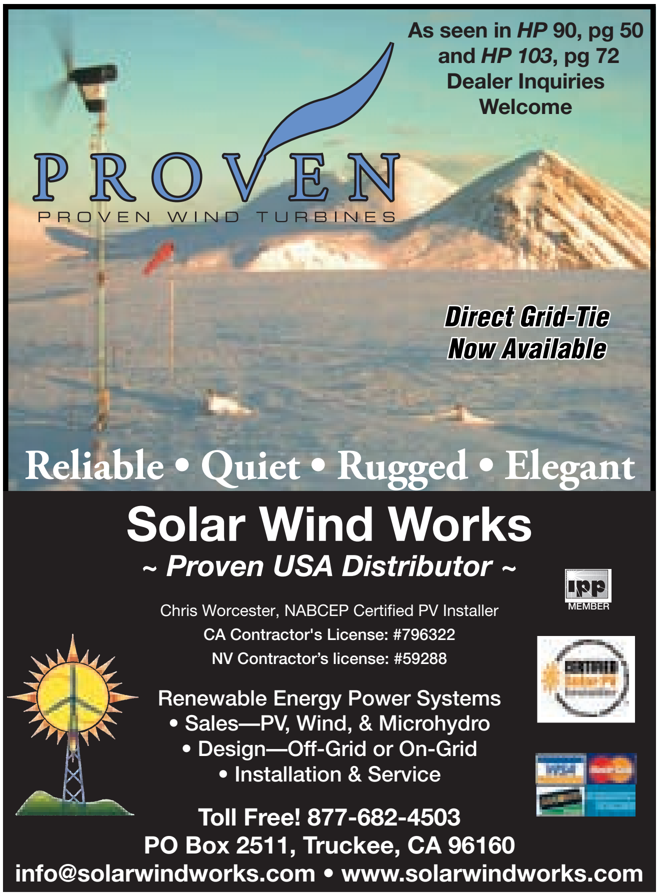
Don Loweburg (don.loweburg@homepower.com) is a solar pioneer in Central California. He owns and operates Offline Independent Energy Systems, and sits on the boards of the California Solar Energy Industries Association and the North American Board of Certified Energy Practitioners (NABCEP).

Sources:

ABC's complaint to the California Energy Commission • www.energy.ca.gov/2005_energypolicy/documents/2004-08-18_hearing/2004-08-18_comments/TENNIS_ASSOC_BUILDERS.PDF

Associated Builders and Contractors (ABC) of California • www.abc.org

CURE • www.sbctc.org/cure/



As seen in HP 90, pg 50
and HP 103, pg 72
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Exploring the Economic Future of Renewables

by Michael Welch

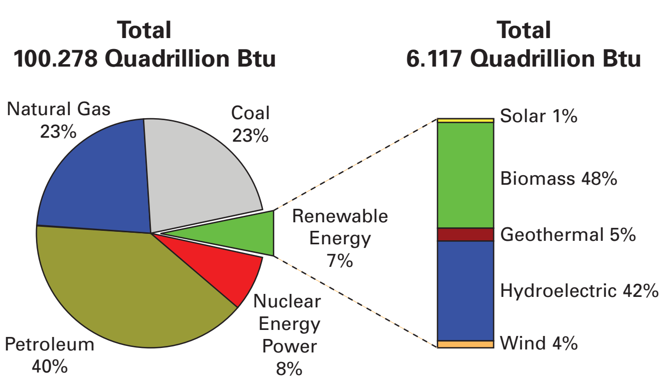
The renewable energy (RE) and energy efficiency (EE) industries have been making slow but steady gains in the United States during recent years. Most folks are aware of the positive environmental contributions that come along with these gains, like less pollution, slower rates of global warming, and less nuclear and other harmful waste. Growth in the RE industry is also offering new employment opportunities for our citizens, and increased support for RE will result in even more economic benefits (jobs and revenues).

In the next several months as the national elections approach, we'll be witnessing the political scene's rising frenzy as candidates crisscross the country telling us what they think we want to hear. If there's one thing that politicians pay attention to nearly as much as the corporations that pony up for their election expenses, it's the economic aspects of the issues they follow. The more we can demonstrate the positive economic gains from increased RE and EE, the more that politicians and corporations will be willing to make the needed changes in energy policy. While it may not necessarily be the most important thing to us, politicians have bought into the 1992 Clinton campaign mantra that "[It's] the economy, stupid."

Assuming (and I do) that RE and EE are critical to the future in all senses, the economic case for those technologies needs to be better made. In September, I came across a heartening presentation on the economic impacts of the RE and EE industries which, for me, make the success of our energy movement seem all the more possible. The presentation was made by Roger H. Bezdek, president of Management Information Services Inc., an economic research and management consulting firm in Washington, D.C. Bezdek earned a Ph.D. in economics at the University of Illinois in Urbana and has experience working on energy issues in both the private and public sectors. He made this presentation at Solar 2007, the annual conference of the American Solar Energy Society held in Cleveland.

While much of the presentation focused on Ohio, the national figures included were impressive. Bezdek presented a snapshot of the current state of the industry, and then projected what jobs and revenues from RE and EE could be in the year 2030, based on three possible scenarios involving public policy and technology development.

U.S. Electricity Generation by Energy Source



Source: Energy Information Administration, 2006

The Scenarios

The first scenario Bezdek presented was the *base case*, a "business as usual" situation that reflects only a continuation of positive governmental policies that currently exist for RE and EE. This scenario assumes that no additional major EE and RE initiatives would be introduced over the next 23 years and that the U.S. EE and RE industries continue to develop according to the general trends and rates of growth experienced over past two decades—which have been steady but slower than many would wish. Bezdek uses this scenario as a basis for comparison to two alternative scenarios.

The base case's resulting renewable development is minimal. Lacking substantial change in policy, EE and RE are not expected to significantly increase their share of the U.S. energy market (renewable energy currently supplies about 7% of market demand). It will just plod along much as it has in the recent past.

U.S. Industries Forecast, 2030

Industry	Annual Revenues (Billions of 2006 Dollars): 2006	Base Case	Moderate Scenario	Aggressive Scenario	Annual Jobs Created (Thousands): 2006	Base Case	Moderate Scenario	Aggressive Scenario
Renewable energy	$39	$95	$227	$597	446	1,305	3,138	7,935
Energy efficiency	933	1,818	2,152	3,933	8,046	14,953	17,825	32,185
Total	$972	$1,913	$2,379	$4,530	8,492	16,258	20,963	40,120

*Source: Bezdek, Roger H. (see Access)

Next, his *moderate* scenario assumes that various incremental (above the base case) federal and state EE and RE initiatives—like R&D support, tax incentives, utilities' RE portfolio mandates, and consumer rebates—are put in place over next two decades. The scenario assumes a continuation of the positive policies that are in place, plus market conditions favorable to renewables (demand exists). As can be seen in the Forecast table, the "moderate" scenario will create many more jobs and revenues than the "base case."

Finally, Bezdek's *aggressive* scenario pushes the envelope on EE and RE industry possibilities, comprised of current or forthcoming technologies. It includes what may be both economically, technologically, and realistically feasible through what he calls a "crash" scenario meaning that something greatly spurs government effort to increase support for RE and EE. Again, this scenario assumes favorable market conditions and the sustained commitment of public policy to ensure that EE and RE achieve higher levels of contribution to the U.S. energy market. It assumes EE and RE industries are available to take the United States in a new direction—appropriate, aggressive public policies at federal and state levels are required and would be sustained over next two decades.

The table shows that all of these scenarios result in huge growth in the RE and EE industries. In the aggressive scenario, RE revenues increase 1,400% and EE revenues increase 320%, while jobs created by RE increase 1,700%, and jobs created by EE increase 300%.

Pushing For the Future

Bezdek's projections shed some light on RE's potential future (see Access for other sources). It is now up to us to make sure it happens. Publicizing the data with letters to the editor and making direct calls to political representatives and candidates are the next step. With information like this, politicians should be more willing to pay attention and take action to address our energy plight.

Renewables & Energy Efficiency Industries:

Growth & Potential

- In 2006, these industries in the United States:
  - Had nearly $1 trillion in gross revenues
  - Created nearly 8.5 million jobs
  - Generated more than $150 billion in federal, state, and local government tax revenues
  - Saved and displaced large amounts of energy
- 2006 EE and RE sales represent substantially more than the combined 2006 sales of the 3 largest U.S. corporations (Exxon Mobil, Wal-Mart, and General Motors)
- RE and EE economies are growing more rapidly than U.S. average
- RE and EE constitute some of the most rapidly growing industries in the world, such as wind, fuel cells, and biofuels.

*Source: Bezdek, Roger H. (see Access)

Access

Michael Welch (michael.welch@homepower.com) has been working for a clean, safe, and just energy future since 1978 as a volunteer for Redwood Alliance and with *Home Power* magazine since 1990.

Management Information Services Inc. • www.misi-net.com

Bezdek, Roger H. "Economic and Jobs Impacts of the Renewable Energy and Energy Efficiency Industries: U.S. and Ohio" • www.ases.org/jobs_report.pdf

Other Sources:

Worldwatch Institute's "Paper #152: Working for the Environment: A Growing Source of Jobs" • www.worldwatch.org

"Apollo Alliance Jobs Report: New Energy for America" • www.apolloalliance.org/jobs/

Union of Concerned Scientists' "Clean Energy Blueprint: A Smarter National Energy Policy for Today and the Future" • www.ucsusa.org

The Energy Future Coalition's "Catalog of the Leading Sources of Information on Job Growth Opportunities in the New Energy Economy" • www.energyfuturecoalition.org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Renewable... Priorities

Ordering RE Possibilities

by Ian Woofenden

Derivation: From Latin prior, *meaning "former" or "prior."*

The perennial question, "Which renewable energy resource is best?" has a perennial answer: It depends. First of all, it depends on what resources you have at your site. There's no sense pining after hydro-electricity if you have no falling water on your property. But you also shouldn't throw up your hands in despair if you don't have as much sun as your cousin in Arizona. You should make the best of the renewable resources available at your site.

The answer also depends on what scale you are considering. Prioritizing renewable energy (RE) technologies is different for homes and ranches than it is for municipal or utility-scale projects. Different people might prioritize the existing renewable energy technologies in different orders. From my knowledge, research, and experience, here are the rankings I'd make for small- and large-scale projects, based on the performance of typical systems. Of course, this ranking will vary, based on design and resource specifics of your individual situation.

On the large scale—municipal to national—the ranking is different. Larger-scale renewables are generally more mature technologies. They have higher reliability and lower cost per delivered kilowatt-hour than their small-scale counterparts.

Note that I'm only considering existing, proven technologies. While new technologies may look promising, my history in the RE industry leads me to wait for a price tag, warranty, and track record before putting time, energy, and money into something new. Meanwhile, the technologies on the market are making energy *today* using natural, abundant, and renewable resources.

On the home-to-ranch scale, I would order the technologies in this way:

Energy efficiency. The first choice on both lists is the most cost-effective and environmentally friendly energy available—the energy you don't have to generate. Conservation (using less) and efficiency (doing more with what you have) should be your first investment, whether you're powering a small cabin, a multinational corporation, a city, or the world.

Solar pool heating is a slam-dunk if you have a pool and sunshine. These systems are low cost, simple to implement, and can significantly reduce nonrenewable energy use.

Microhydro-electric systems take a very concentrated resource—water under pressure—and make a lot of electricity using a modest amount of infrastructure.

Solar hot water systems, for domestic hot water (and where appropriate, space heating), are the most cost-effective RE technologies for the typical home.

Photovoltaic (solar-electric) systems are still relatively expensive up front, but many homeowners choose this technology over solar hot water because of its very high reliability and simplicity to maintain.

Wind electricity looks very attractive to the uninitiated, and when it works well, it can produce electricity very inexpensively. But it often doesn't work well on the home scale, and when you factor in the cost of downtime, repair, and replacement, this technology ends up at the bottom of my list for typical home-scale systems.

At the utility scale, after energy efficiency, my simplified ranking looks like this:

Hydro-electricity on a large scale can produce some of the least costly electricity available. Of course, it is not without its impacts, with dammed rivers flooding landscapes and communities, and affecting fish and other animals.

Wind electricity, on farms or with single utility-scale units for large businesses and institutions, is one of the fastest-growing RE technologies, and doesn't suffer from the lack of reliability of its small-scale cousins.

Biomass for electricity generation includes waste from agriculture, forestry, and municipalities, as well as dedicated energy crops. Behind hydro-electricity, biomass is the single largest source of renewable electricity in the United States today.

Geothermal energy—tapping the heat in the earth—is not as widely available as some of the other resources, but can make sense when it is. Steam turbines running on the earth's heat energy are used in many regions around the world.

Concentrating solar thermal plants use large reflective troughs, dishes, or tracked mirrors that concentrate the sun's heat and make steam to generate electricity. Plants in California and Nevada cover hundreds of acres of desert, with generating capacities of several hundred megawatts.

Photovoltaics are very reliable, but so far, the economics don't improve dramatically when scaled up, though this could change as the industry develops. Business incentives in some areas make the financial case for PV very inviting.

So what are your priorities? My prioritized lists are big-picture rankings, assuming equal resources. But in the real world, each region and property has more or less of each resource. In my book, your top priority should be to implement energy conservation and efficiency strategies, whether it is in your home, business, region, country, or world. Then move toward using your local renewable resources, and choose them over nonrenewables, which in the long run are expensive and unsustainable.

Access

Ian Woofenden's (ian.woofenden@homepower.com) home in Washington's San Juan Islands has no uranium, coal, or oil deposits, nor access to falling water or free hydrogen. But it does have reasonable sun and wind resources, so that's what his family uses to heat water and make electricity.

There's No Place Like My Home

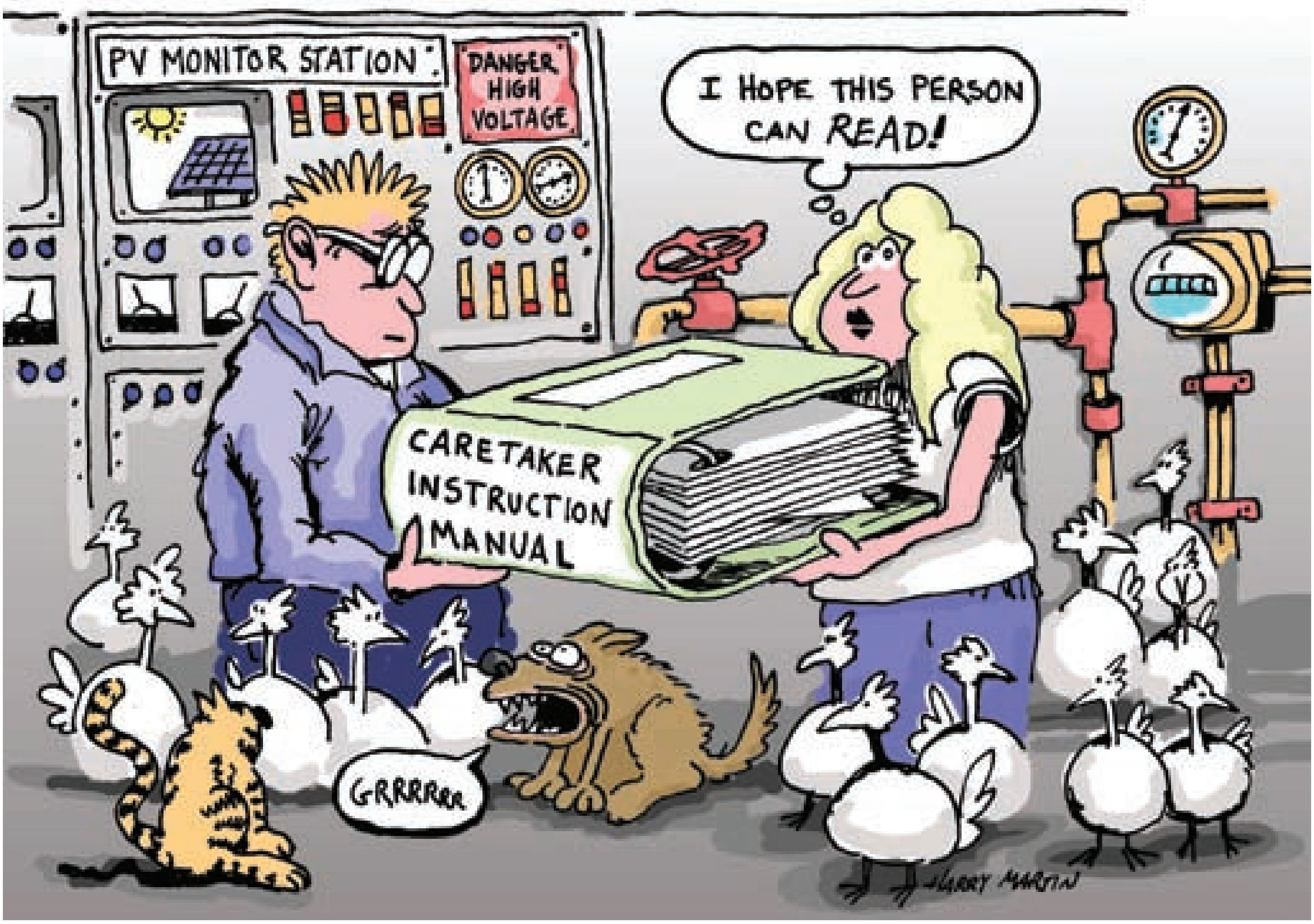
by Kathleen Jarschke-Schultze

My husband Bob-O and I have realized that when you own a business, you are married to it. And, when you run that business from your home, any time you can get away from the phones is a vacation. Unfortunately, leaving our off-grid, renewable energy (RE) powered home in the hands of a caretaker can detract from the peace of mind that a getaway can offer.

Leaving Home

Since we live off grid and use solar, wind, and microhydro to power our home and business, it is a little harder to find caretakers who are willing to stay at our homestead. It is even harder to find caretakers who are RE-savvy. Because of our busy business and active homestead, complete with a dog, chickens, worms, and other living things, whenever we leave our home for three days or more, we must find someone to be there for us.

Further complicating matters is our homestead's remoteness, although it's not really that hard to find us. Many people mistakenly think they have gone too far and turn back before they get here. I had one guy come to pick up PV modules. I told him that our house was 1.8 miles from the pavement. When he arrived, he claimed that he had driven at least 3 miles up the dirt road to get to our house. I explained that the first time up an unknown road can seem endless, but it really was only 1.8 miles. I saw him later and he admitted he



had set his odometer on the way back—and that I was right. Now I have a map that I can e-mail, fax, or mail so people can find us easier.

Folks can locate us, but the big problem is finding someone who doesn't mind being out in the country and who knows a little (at least) about RE. It also really helps if they know a little about gardening and poultry. The absolute best is if they also can answer phones and take good notes to handle our business calls while we're away. However, it is rare that a person with these skills is free to stop what they are doing to care-take when we need it.

Home Manual

Because most of our caretakers are new to several or all aspects of our homestead, I have written an instruction manual. The manual consists of individual sheets in a three-ring binder so it can easily be updated. I have written a section on each care subject. There is a chapter each on the dog, the chickens, the garden, the office, the electrical system, the water system, the appliances, the satellite computer system, and the satellite TV system.

There are "how-tos" and "why-fors," and a couple of "what-the-hecks" on every subject. There are friends' phone numbers to call if the caretaker gets confused or confounded. I have even documented some common troubleshooting procedures. It seems like every time we leave, a new circumstance arises for our house sitter, so I keep adding to the manual. Bob-O likes to add his comments in the margins. He says it is an amusing read in any case.

Home Alone

I have to admit that, through the years, some of our house sitters have had exciting times here at the old homestead. Once, when we were at the SolWest renewable energy fair in John Day, Oregon, we got calls from neighbors that a wildfire was raging close to our home.

Although our next neighbor down the creek evacuated our caretaker and removed some of our more precious items, the young man who was caring for our homestead didn't panic. He had worked on a fire crew on the Salmon River. So he set up hoses and sprinklers before he left and didn't leave until he absolutely needed to. He was swell.

Home Grown

We have had sitters who are very good at one aspect of caring for our homestead but are dismal in others. One guy was great in the office and took excellent phone notes, but was really disastrous in the gardening department. While the chickens fared well under his care, the green beans, not so much. When green beans mature from flowers to bean pods, you have to pick them regularly to keep the plant producing. This concept was a little hazy for our sitter. Being a bachelor from town, he was probably just overwhelmed with garden vegetables. When we got home, some plants were stressed, but I didn't lose any.

A woman who house-sat for us several times actually lived with off-grid RE systems herself and was comfortable with the responsibilities of keeping tabs on our home system. No problems there. Being a country woman, she also was savvy about gardening and livestock care. I was explaining about the kitchen scraps for the composting worm bed and the scraps for the chickens. To my gratification she said, "Don't worry, I know the difference between the two." In short, worm compost can be rotten, chicken scraps cannot.

Home-a-Cide

Probably the worst experience we had with a caretaker was just a few years ago. We had arranged for a couple to come check on our home every other day while we attended the Midwest Renewable Energy Fair in Amherst, Wisconsin. I had a few last-minute instructions and left them in an envelope taped to the door at eye level. I thought they would surely find it as soon as they arrived.

A week later we returned. Our first clue that something had gone awry was the untouched envelope on the door. We immediately checked the watering system for the garden, orchard, and vineyard. All the filters were clogged and nothing was getting watered. Our sitters had totally bagged on us. I lost several plantings in the garden.

Two weeks later they called with an excuse that did not impress us. And then they had the nerve to ask if they still had the caretaking gig during our next trip, a yearly working vacation where we power up five stages and numerous food booths with solar electricity at a large country fair. The answer was, of course, absolutely not.

Homework

It can be difficult to find the perfect person to look after an off-grid, RE-powered homestead. The problems encountered can be weather-driven or operator error. And livestock and pets are their own universe of responsibility. Compared to an urban utility-intertied system, our homestead is rife with possible pitfalls and teeming with the opportunity for adventures (as I like to call them). Even so, with a little instruction and a lot of common sense, any responsible person can generally handle the job.

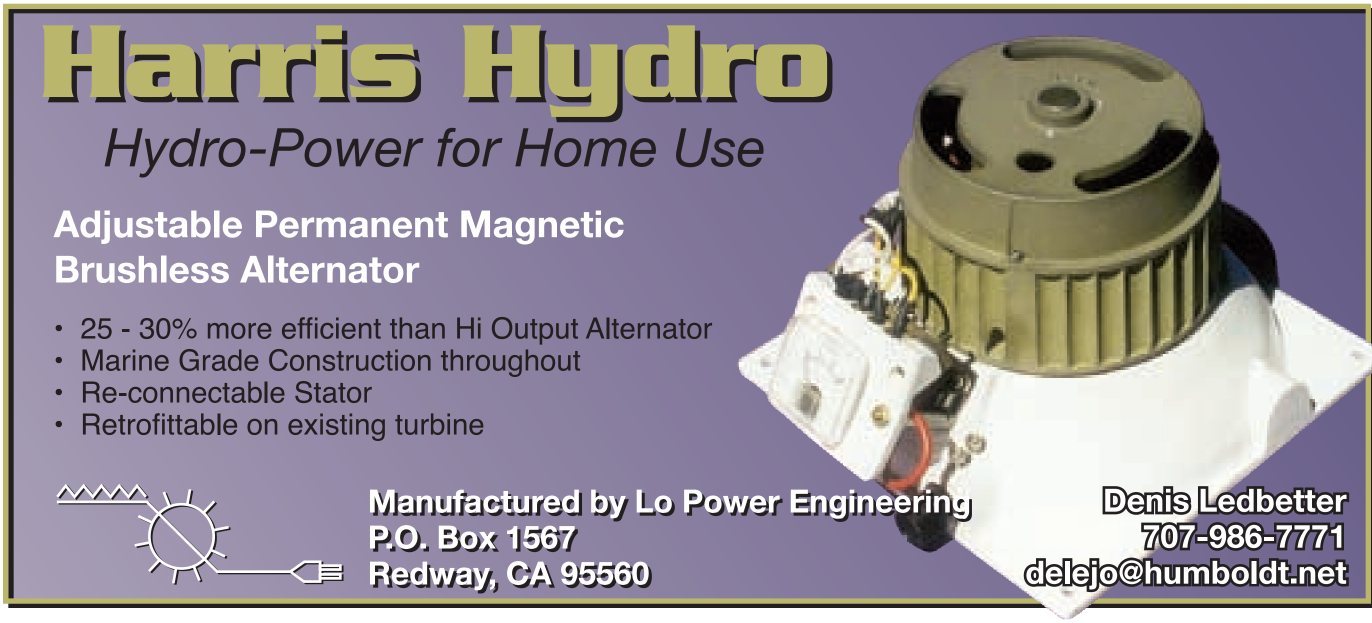
I just have to remember that because I've lived with off-grid RE systems for such a long time, some actions are automatic on my part—such as turning on plug strips and then the appliance, or glancing at the wall-mounted battery monitor before starting a load of laundry, or turning out lights when I leave a room. These simple acts can be revolutionary for the non-initiated.

Homecoming

Although it's great to get away from the phones and the office even if just for awhile, over the years we've found that it is even better to come home. After even a short absence, we walk in the door and sigh with contentment—we are home. We love our home. It is ours; it is us. And with all its eccentricities and quirks, it is just where we want to be.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is beading silverware at her off-grid home in northernmost California.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RE happenings

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Dec. 3–5, '07. San Francisco (again Feb. 25-27, '08 in Santa Monica). PV System Design for Engineers & Designers. Course on producing PV design documents. Info: www.sunengineer.com/workshops.htm

Arcata, CA. Workshops & presentations on RE & sustainable living. Campus Center for Appropriate Technology, Humboldt State Univ. • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar domestic hot water, space heating, alternative fuels, straw bale building, green building, women's PV courses & more. Solar Energy Intl. (SEI) • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

IOWA

Feb. 20–22, '08. Des Moines. Forum on Energy Efficiency in Agriculture. Info: ACEEE • 202-429-8873 • agforum@aceee.org • www.aceee.org

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

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Hudson, MA. Workshops: Intro to PV; Advanced PV; RE Basics; Solar Hot Water & more. Info: The Alternative Energy Store • 877-878-4060 • support@altenergystore.com • http://workshops.altenergystore.com

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West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

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New Bloomfield, MO. Workshops, monthly energy fairs & other events. Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

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Dec. 1, '07. Manchester, NH. Home Energy Conference. Incorporating RE, efficiency, green building, geothermal, biofuels & other sustainable technologies into the home. Info: NH Sustainable Energy Assoc. • 603-497-2302 • nh.sustain.energy@tds.net • www.nhsea.org

Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO

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Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

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Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

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Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org/psea.htm

TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group, quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

WASHINGTON D.C.

Mar. 4–6, '08. Washington Intl. RE Conference (WIREC 2008). Trade show & business conference. Info: ACORE • 202-393-0001 ext. 7582 • weirich@acore.org • www.americanrenewables.org

WISCONSIN

Amherst, WI. Dec. 1, '07 (again Feb. 21, '08 & Mar. 5, '08): Intro to Solar Water & Space Heating System. Dec. 2–4, '07 (again Feb. 22–24, '08 & Mar. 26–28, '08): Installing a Solar Water Heating System (hands-on). Jan. 26, '08: Living Sustainably. Info: Artha Sustainable Living Center LLC • 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

Custer, WI. MREA '07–'08 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

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Feb. 17–21, '08. Adelaide, S. Australia. Intl. Solar Cities Congress. Support cities in UN energy & climate policies by stimulating interest in RE & energy efficiencies. Info: Plevin & Associates • 61-8-8379-8222 • events@plevin.com.au • www.solarcitiescongress.com.au

COSTA RICA

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Feb. 2–10, '08. Durika. Solar Electricity for the Developing World. Hands-on workshop. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com • www.durika.org

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Mar. 17–20, '08. Cayo Coco, Ciego de Ávila province. CUBASOLAR 2008. Intl. energy, environment & sustainable development. Info: CUBATUR • 205-99-49 • gavilan@cubaenergia.cu • www.cubaenergia.cu

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Jun. 12–14, '08. Munich. Intersolar 2008. Solar developments exhibition & forum. Info: www.intersolar.de

NEW ZEALAND

Jan. 26–27, '08. Canterbury. Sustainability Expo. PV, wind, Solar hot water, energy efficient building design, housing, transport & other sustainable technologies. Info: Solar Electric Specialists Ltd. • 027-457-6527 • www.sustainabilityexpo.co.nz

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1) Outside-County	779	690
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f. Total Distribution	46,860	55,229
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17. I certify that the statements made by me above are true and complete. Scott M. Russell, Operations Director, 9/21/07.

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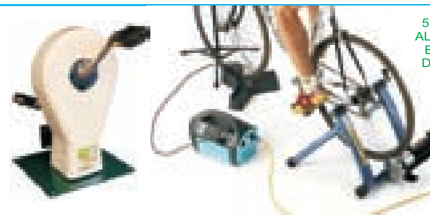

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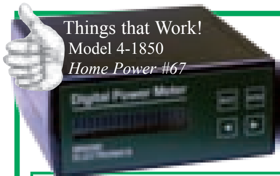

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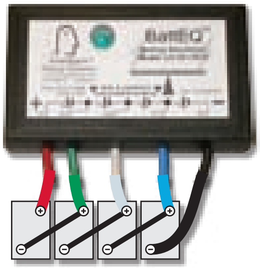

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RE People

Who: Kevin & Katie Reily

Where: Chapel Hill, North Carolina

When: 2006 to present

What: Solar-electric & solar hot water systems

Why: Sound financial & environmental investment

Kevin and Katie Reily have focused their energy and efforts on setting an example of how American families can have lifestyles that are both sustainable and comfortable. Kevin is dedicated to right livelihood and pioneered a first-of-its-kind vinyl siding reclamation and recycling operation. Katie is a speech-language therapist in private practice, a people person with a strong environmental bent, and she loves to travel.

"A year after I graduated from high school, I started a little farm in eastern Tennessee and remodeled the old farmhouse, where I cooked and heated with wood," says Kevin. "Katie and I designed a passive solar house, but never got around to building it before we moved to Atlanta, where our four children were born. My interest in renewable energy went underground until we bought rural property in North Carolina."

In 1993, Kevin and Katie bought 7 1/2 acres outside Chapel Hill, remodeled an old garage on the property as a temporary dwelling, and lived in it until Hurricane Fran hit in 1996. The stormed turned out to be a literal windfall for them, and they used fallen oak trees to build a post-and-beam home attached to the garage. Many other materials in the house are also reclaimed or recycled, from windows to the kitchen sink to a floor made from old chimney bricks. To further minimize resource use, the house was designed with deep overhangs to shade windows in the summer. Even during North Carolina's hot and humid summers, it needs no air conditioning.

The Reilys' renewable energy systems include a wood heater and a solar thermal system for space heating and domestic hot water, and a grid-tied 2.4-kilowatt solar-electric system with battery backup. The battery bank was sized to support water pumping, refrigeration, office appliances, and pumps for the radiant heating system during the occasional utility outages that they experience. Two low-tech solar energy dryers—sturdy clotheslines—round out the Reilys' RE system.

Renewable energy interests the Reily family for several reasons: "We feel good investing in an industry that has potential to reduce global warming. Strong tax incentives have made it economically attractive for us to invest in RE now. And having a backup system when the utility goes down is a very useful bonus."

Ed Witkin of Carrboro Solar Works installed the Reilys' solar-electric system and has known the family for years. Their kids went to school together, and Ed has grown to respect the family environment that Kevin and Katie have built—and the environmental consciousness they have. "The Reilys' home is alive with the work they're all doing to nurture themselves and the Earth."

—Ian Woofenden

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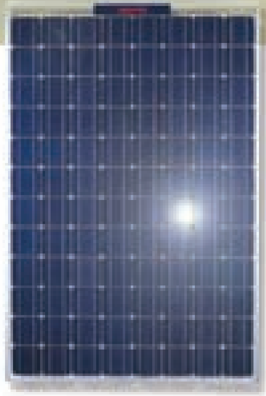

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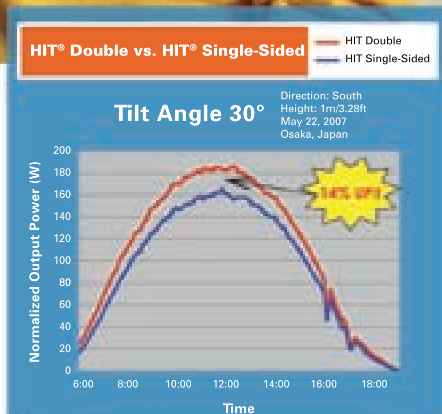

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